# Scientific foundations of the combination of diagnostic and surgical approaches in the treatment of cardiac patients



**Fundamentos científicos de la combinación de enfoques diagnósticos y quirúrgicos en el tratamiento del paciente cardíaco**

Markha Ismailovna Akhmadova, North Ossetian State Medical Academy, 40 Pushkinskaya str., Vladikavkaz, 362025, Russia.
akhmadovamarkha@icloud.com https://orcid.org/0009-0003-5423-4435
Alexander Arkadievich Yaruhin, I.M. Sechenov First Moscow Medical University, 2/4 Bolshaya Pirogovskaya str., Moscow, 119991, Russia.
canek_yarukhin@mail.ru https://orcid.org/0009-0008-6686-9282
Maria Vyacheslavovna Pyatykh, I.M. Sechenov First Moscow Medical University, 2/4 Bolshaya Pirogovskaya str., Moscow, 119991, Russia.
mary-pyatih@mail.ru https://orcid.org/0000-0003-0412-4708
Jamilya Soltan-Muratovna Doyunova, I.M. Sechenov First Moscow Medical University, 2/4 Bolshaya Pirogovskaya str., Moscow, 119991, Russia.
Doyunovaj@gmail.com https://orcid.org/0009-0005-4692-5476
Angelina Nasirovna Babaeva, I.M. Sechenov First Moscow Medical University, 2/4 Bolshaya Pirogovskaya str., Moscow, 119991, Russia.
angelinababaeva7@gmail.com https://orcid.org/0009-0007-1717-1294
Alisa Alexandrovna Gostyaeva, Siberian State Medical University, 2 Moskovsky trakt, Tomsk, 634050, Russia.
gostyaeva.alice@gmail.com https://orcid.org/0009-0001-6759-9826
Valeriia Leonidovna Shikhgasanova, Russian University of Medicin, 4 Dolgorukovskaya str., Moscow, 127006, Russia.
valera_lera555_kim@mail.ru https://orcid.org/0009-0008-3305-4239
Received: 02/20/2025 Accepted: 04/19/2025 Published: 05/12/2025 DOI: http://doi.org/10.5281/zenodo.15535783

## Abstract

Modern cardiology is rapidly developing, integrating diagnostic and surgical approaches to improve the effectiveness of treatment of patients with cardiovascular diseases. This paper examines the scientific basis for combining these methods, emphasizing their importance for personalized medicine. The role of modern diagnostic technologies such as magnetic resonance imaging (MRI), computed tomography (CT), ultrasound examinations and laboratory tests is emphasized, which make it possible to accurately assess the patient's condition and identify pathological changes in the early stages. At the same time, the possibilities of minimally invasive surgical interventions, including coronary angioplasty, stenting, and procedures using robotic systems, are being analyzed. Special attention is paid to the principles of interaction between diagnosis and surgical treatment, which makes it possible to optimize therapeutic strategies and minimize the risks of complications. The article also highlights the prospects for the development of hybrid technologies that combine diagnosis and treatment within a single protocol, as well as the importance of an interdisciplinary approach in managing complex clinical cases. It is emphasized that a successful combination of diagnostic and operative methods requires not only high-tech equipment, but also a deep understanding of the pathophysiology of diseases, as well as continuous professional development of doctors. Thus, the integration of these approaches contributes to improving the quality of medical care, reducing treatment costs and improving prognosis for patients with cardiac diseases.

**Keywords**: cardiology, diagnostics, surgical treatment, minimally invasive technologies, personalized medicine, hybrid methods.

## Introduction

Cardiovascular diseases (CVD) remain one of the leading causes of death and disability worldwide, despite significant advances in medicine over the past decades[1]. Effective treatment of these diseases requires an integrated approach that combines modern diagnostic methods and surgical interventions. In the context of the growing prevalence of CVD and the increasing complexity of their clinical manifestations, the relevance of developing evidence-based strategies for combining diagnosis and treatment becomes especially obvious.

Diagnostic technologies play a key role in modern cardiology, providing an accurate assessment of the state of the cardiovascular system and the detection of pathological changes at an early stage. However, diagnosis in itself is not an end in itself – it serves as the basis for making decisions about the need and type of therapeutic or surgical intervention. Surgical approaches, in turn, have evolved from traditional open surgeries to minimally invasive procedures that minimize injury, accelerate patient recovery, and reduce the risk of complications. Nevertheless, the success of any surgical intervention directly depends on the quality of the preliminary diagnosis, which determines the treatment tactics and its technical parameters.

The integration of diagnostic and operative methods is becoming an important direction in the development of modern cardiology. Hybrid technologies that combine diagnosis and treatment within a single protocol make it possible to optimize the treatment process and increase its effectiveness. For example, simultaneous angiography and stenting or the use of intraoperative imaging opens up new opportunities for managing complex clinical cases [2]. At the same time, an interdisciplinary approach involving the interaction of specialists of various profiles becomes an integral part of the successful treatment of patients with CVD.

The purpose of this work is to examine the scientific basis for combining diagnostic and surgical approaches in the treatment of cardiac patients, emphasizing their importance for personalized medicine. Special attention is paid to the role of modern technologies such as minimally invasive surgical techniques, artificial intelligence and bioengineering, as well as the prospects for further development of this field.

## Materials and methods

Various theoretical research methods were used in the preparation of this work, which made it possible to systematize and analyze scientific data on the combination of diagnostic and surgical approaches in the treatment of cardiac patients. These methods provide a reliable basis for the formulation of conclusions and recommendations. In particular, a detailed review of modern scientific literature was conducted, including articles from peer-reviewed journals, monographs, clinical guidelines and guidelines on cardiology. Special attention was paid to publications devoted to innovative diagnostic and surgical technologies.



Databases such as PubMed, Scopus, Web of Science, Cochrane Library and eLibrary were used, which provided up-to-date information on modern advances in the diagnosis and treatment of cardiovascular diseases. An analysis of the literature has helped to identify key trends, problems and prospects in the development of hybrid technologies, minimally invasive methods and interdisciplinary interaction.

In addition, various diagnostic and operational methods were compared in terms of their effectiveness, safety, accessibility and economic feasibility. For example, traditional open surgeries have been compared with minimally invasive procedures such as stenting or robotic surgery.

Based on the analysis of scientific data, a systematization of modern approaches to the diagnosis and treatment of cardiovascular diseases was carried out. Summarizing the research results allowed us to formulate general principles for integrating diagnostic and operational approaches.

To better understand the interaction between the diagnostic and surgical stages of treatment, modeling and schematic representation of the processes were used, which included a description of the sequence of actions, starting from primary diagnosis to surgical intervention and postoperative follow-up.

The application of the above theoretical methods has provided a comprehensive analysis of the scientific foundations of the combination of diagnostic and surgical approaches in the treatment of cardiac patients. These methods allowed not only to systematize existing knowledge, but also to propose new ideas for improving clinical practice. The results obtained are important for the development of personalized treatment strategies, the introduction of innovative technologies and improved prognosis for patients with cardiovascular diseases.

Heart pathologies are becoming more widespread in the world today, moreover, the prevalence of this condition is steadily increasing. The increase in cases of heart failure may be partially related to an aging population and a higher incidence of cardiovascular risk factors such as hypertension, diabetes, and obesity[3]. Cardiac pathologies entail a significant economic burden, as the health care costs associated with this condition reach billions of dollars every year[4]. In addition to the financial consequences, such pathologies significantly worsen people's overall well-being. This is evidenced by the appearance of symptoms such as difficulty breathing (shortness of breath), constant fatigue (fatigue) and decreased ability to engage in physical activity (exercise intolerance). Ultimately, these symptoms contribute to a marked reduction in life expectancy[5].

The treatment of cardiac pathologies has changed significantly in recent decades, mainly due to advances in research and clinical practice. Pharmacological therapies such as angiotensin converting enzyme (ACE) inhibitors, beta blockers, angiotensin receptor blockers (ARBs), and diuretics have historically served as a fundamental approach to the treatment of heart failure. The main purpose of these drugs is to alleviate symptoms, reduce fluid retention, and improve heart function[6]. In addition, implantable devices such as implantable cardioverter defibrillators (ICDs) and cardiac resynchronization therapy (CRT) have become the most important tools in the arsenal of combating heart diseases, demonstrating a significant reduction in mortality and hospitalization among certain patient groups[7]. Heart transplantation has consistently been recognized as the preferred treatment method for people with end-stage heart failure, offering a vital opportunity for people with persistent symptoms and impaired heart function. However, the limited availability of donor organs limits its potential implementation. Effective treatment of cardiac pathologies requires an integrated approach that combines modern diagnostic methods and surgical interventions.

Diagnosis plays a key role in identifying pathological changes at an early stage, predicting the risks of complications, and developing personalized therapeutic strategies. Modern technologies such as magnetic resonance imaging (MRI), computed tomography (CT), echocardiography, and laboratory tests allow doctors to obtain accurate information about the patient's cardiovascular system[8]. However, diagnosis in itself is not an end in itself – it serves as the basis for making decisions about the need and type of treatment, including drug therapy or surgery.

Surgical approaches in cardiology have also undergone significant changes due to the development of minimally invasive technologies. Procedures such as coronary angioplasty, stenting, implantation of pacemakers, and the use of robotic systems can minimize the trauma of interventions, shorten patient recovery time, and reduce the risk of postoperative complications. Nevertheless, the success of any surgical intervention directly depends on the quality of the preliminary diagnosis, which determines the treatment tactics and its technical parameters[9].

The integration of diagnostic and operative methods is becoming an important direction in the development of modern cardiology. Hybrid technologies that combine diagnosis and treatment within a single protocol make it possible to optimize the treatment process and increase its effectiveness. For example, simultaneous angiography and stenting or the use of intraoperative imaging opens up new possibilities for managing complex clinical cases. At the same time, an interdisciplinary approach involving the interaction of specialists of various profiles becomes an integral part of the successful treatment of patients with CVD.

Diagnostic technologies play a key role in modern cardiology, providing an accurate assessment of the state of the cardiovascular system and the detection of pathological changes at an early stage. The development of medical imaging, laboratory research methods and functional diagnostics has significantly expanded the possibilities for timely detection of diseases such as coronary heart disease, arterial hypertension, heart defects and chronic heart failure[10].

Modern diagnostic methods, such as magnetic resonance imaging (MRI), computed tomography (CT), ultrasound (echocardiography, Dopplerography) and radionuclide methods, allow not only to visualize the anatomical features of the heart and blood vessels, but also to assess their functional state. For example, echocardiography provides information about the size of the chambers of the heart, the thickness of the walls, the condition of the valve apparatus and the contractility of the myocardium. MRI and CT, in turn, make it possible to study in detail the structure of the coronary arteries, identify areas of stenosis or occlusion, and evaluate myocardial perfusion.

Laboratory tests, including blood tests for biomarkers (e.g., troponins, natriuretic peptide), are an important addition to instrumental diagnostic methods. They help to confirm the presence of acute coronary syndrome, assess the degree of myocardial damage and predict the risk of complications. Functional tests, such as exercise tests and Holter monitoring, make it possible to assess the response of the cardiovascular system to physical activity and identify hidden rhythm or conduction disturbances[11].

Of particular importance is the possibility of diagnosis in the early stages, when the clinical manifestations of the disease may be minimal or absent altogether. Early detection of pathological changes allows treatment to begin at the preclinical stage, which significantly reduces the risk of serious complications such as myocardial infarction, stroke or chronic heart failure. In addition, accurate diagnosis serves as the basis for making decisions about the need and type of surgery, providing a personalized approach to the treatment of each patient.

Diagnosis in itself is not an end in itself — it serves as the basis for making decisions about the need and type of therapeutic or surgical intervention. Modern diagnostic methods provide doctors with detailed information about the patient's condition, allowing them to accurately determine the nature of the disease, its stage and prognosis. These data are becoming critically important for choosing the optimal treatment strategy, whether it is drug therapy, minimally invasive procedures, or open surgery.

Surgical approaches, in turn, have evolved from traditional open surgeries to minimally invasive procedures that minimize injury, accelerate patient recovery, and reduce the risk of complications. For example, instead of cardiac cavities such as coronary artery bypass grafting, endovascular techniques such as coronary angioplasty and stenting are widely used today. Such procedures are performed through small punctures in the vessels, which significantly reduces the patient's stay in the hospital and reduces postoperative discomfort.

Technology development has also facilitated the introduction of robotic systems such as the da Vinci Surgical System, which allow complex operations to be performed with high precision with minimal impact on the body. Such systems are especially effective in cases where precision manipulations are required on small structures of the heart or blood vessels[12]. In addition, the use of intraoperative imaging, such as three-dimensional echocardiography or X-ray angiography, allows surgeons to monitor the process in real time, which increases the safety and effectiveness of interventions.

Minimally invasive technologies not only reduce the burden on the patient's body, but also allow them to return to normal life faster, which is especially important for elderly patients and people with concomitant diseases, for whom traditional operations may be contraindicated due to high risks. However, the success of minimally invasive procedures largely depends on the quality of the preliminary diagnosis. Accurate visualization, functional tests, and laboratory analyses help determine the optimal treatment approach, plan the course of surgery, and anticipate possible difficulties[13].

Accordingly, the combination of advanced diagnostic technologies and modern operational approaches creates a synergistic effect that maximizes treatment outcomes and minimizes risks to the patient. Diagnosis forms the foundation on which successful surgical intervention is built, and minimally invasive methods ensure safety, effectiveness and comfort for the patient. This integrated approach is becoming the standard of modern cardiology, opening up new horizons for the treatment of cardiovascular diseases.

Special attention is paid to functional tests, which help to assess not only anatomical, but also hemodynamic features of the heart. These research methods play a key role in understanding how the patient's cardiovascular system copes with physical exertion, stress, or other factors affecting its functioning. Functional tests such as stress tests, Holter monitoring, treadmill tests, and radioisotope ventriculography can reveal hidden circulatory disorders, myocardial ischemia, rhythm and conduction disturbances that may be unnoticeable during a standard examination[14].



For example, exercise tests (bicycle ergometry or treadmill test) allow you to evaluate the heart's response to physical activity, which is especially important for the diagnosis of coronary heart disease. Such tests help to identify signs of ischemia, such as changes in the electrocardiogram or the appearance of angina symptoms that occur when the heart's oxygen demand increases. Holter monitoring, in turn, provides information about the work of the heart for a long time (usually 24-48 hours), which allows you to identify episodes of arrhythmias or transient ischemia, which may not appear during a short examination[15].

Radioisotope ventriculography makes it possible to assess the contractility of the heart and the volume of its chambers, which is especially important in the diagnosis of heart failure or after a myocardial infarction. These data are crucial for determining treatment tactics: for example, a patient with severe left ventricular dysfunction may require surgery to implant a pacemaker or defibrillator, while for less severe disorders, drug therapy may be sufficient.

Functional tests also help to evaluate the effectiveness of treatment already performed. For example, repeated exercise tests after a course of rehabilitation or surgery can determine how much exercise tolerance has improved and the likelihood of complications has been reduced, which is especially important for patients with chronic diseases such as hypertension or coronary heart disease, where dynamic monitoring is a key element of condition management.

The success of surgical treatment largely depends on the accuracy of the preliminary diagnosis, which determines the tactics of the intervention and its technical parameters. Modern medicine demonstrates that surgical treatment, especially in cardiology, is impossible without a clear understanding of the patient's condition obtained through a comprehensive diagnosis. Based on diagnostic data, the doctor makes decisions about the need for surgery, selects the most appropriate method of intervention and plans all stages of the procedure[16].

Diagnosis allows you to accurately identify the localization of the pathological process, its nature and severity. For example, in coronary artery disease, coronary angiography helps to identify areas of coronary artery stenosis or occlusion, their extent and significance for the blood supply to the myocardium. These data directly influence the decision on the choice between stenting, angioplasty or coronary artery bypass grafting. Without accurate visualization, it is impossible to plan the technical aspects of the operation, such as the size of the stent, the installation location, or the need for additional manipulations[17].

In addition, diagnosis plays a key role in assessing the risks associated with surgery. For example, in patients with severe left ventricular dysfunction or multiple concomitant diseases, open surgery may be associated with a high risk of complications. In such cases, minimally invasive methods such as endovascular interventions become preferred[18]. Functional tests, including stress tests and radionuclide studies, help to assess the tolerability of surgery and predict possible complications.

Diagnostic accuracy is also critically important for planning the technical parameters of an operation. For example, when implanting pacemakers or defibrillators, it is necessary to take into account the patient's anatomical features, the location of large vessels and the condition of the myocardium. Three-dimensional reconstruction of images obtained using MRI or CT allows surgeons to simulate the intervention process in advance and minimize the likelihood of errors[19]. Similarly, in valvular surgery or the restoration of congenital heart defects, preoperative diagnosis provides an understanding of anatomical features and helps to choose the optimal size and type of implantable devices.

It is especially important to emphasize the role of diagnostics in monitoring the results of surgery. Intraoperative imaging, such as echocardiography or angiography, allows monitoring the implementation of the intervention in real time and correcting it if necessary[20]. After the operation is completed, diagnostic methods are used to evaluate its effectiveness, identify possible complications, and develop a plan for further patient monitoring.

Thus, diagnosis is an integral part of successful surgical treatment. It provides the doctor with all the necessary information to make informed decisions, reduce risks and improve the accuracy of surgical procedures. With the development of modern technologies, where minimally invasive methods are becoming the standard, the importance of high-quality diagnostics is only increasing, as it forms the foundation for achieving the best clinical results.

The role of an interdisciplinary approach in modern cardiology cannot be overestimated, since it involves close cooperation between specialists of various profiles: cardiologists, surgeons, radiologists, anesthesiologists, internists, intensive care specialists and other experts. Such cooperation is necessary to manage complex clinical cases that require comprehensive data analysis and balanced decision-making[21]. In the context of the increasing complexity of the diagnosis and treatment of cardiovascular diseases (CVD), an interdisciplinary approach is becoming a key success factor in providing high-quality medical care.

Cardiologists play a central role in the diagnosis and conservative treatment of patients, determining management tactics at the initial stages. However, when complex pathologies are identified or surgery is needed, their interaction with surgeons becomes critically important. Surgeons, in turn, rely on accurate data provided by radiologists who perform imaging studies such as MRI, CT or angiography to plan the technical aspects of the operation. This is especially important when performing minimally invasive procedures, where accuracy is of paramount importance[22].

Anesthesiologists also play a key role in managing complex clinical cases. Their task is not only to ensure safe anesthesia during surgery, but also to maintain a stable patient's condition in the postoperative period. For example, in patients with severe heart failure or multiple concomitant diseases, anesthetic support requires special attention and careful planning. The joint work of anesthesiologists and surgeons minimizes the risks of complications and ensures a comfortable recovery of the patient.

In addition to providing data for preoperative planning, radiologists can actively participate in the procedures themselves, such as endovascular interventions. Their skills in interventional radiology allow them to perform complex manipulations, such as stent placement or vascular embolization, making them indispensable members of an interdisciplinary team.

Therapists and intensive care specialists provide long-term monitoring of patients, monitor the effectiveness of treatment and timely identify possible complications[23]. This is especially important for patients with chronic diseases such as hypertension, coronary artery disease, or chronic heart failure who require constant adjustment of drug therapy[24].

The following models have been developed to visually represent the interaction between diagnostic and surgical stages of treatment, as well as to analyze hybrid technologies. Such models help to better understand the sequence of actions, their interrelationships, and the benefits of integrating different approaches.

The general model of interaction between diagnosis and surgical treatment (Fig. 1) demonstrates the sequence of actions from primary diagnosis to surgical intervention and postoperative follow-up.

**The patient complains**
↓
**Primary diagnosis: medical history, examination, ECG**
↓
**Instrumental diagnostics: MRI/CT/EchoCG**
↓
**Laboratory tests: biomarkers, lipidogram**
↓
**Data analysis → Decision-making on treatment tactics**
↓
**Drug therapy ↔ Surgical intervention**
↓
**Minimally invasive procedures: stenting, angioplasty**
↓
**Postoperative follow-up: monitoring, rehabilitation**
↓
**Monitoring the effectiveness of treatment: re-diagnosis**

Fig. 1 General model of interaction between diagnosis and surgical treatment

Within the framework of this model, the sequence of treatment stages is clearly shown, the importance of diagnosis at each stage is emphasized, and the possibility of adjusting treatment tactics based on postoperative observation data is reflected.

A model of hybrid technologies (simultaneous angiography and stenting) (Fig. 2). demonstrates the process of simultaneous diagnostic and therapeutic procedures, which is an example of hybrid technology.

**The patient is admitted with suspected coronary artery disease**
↓
**Coronary angiography → Detection of coronary artery stenosis**
↓
**Assessment of the significance of stenosis → Making a decision on stenting**
↓
**Stenting in the same procedure**
↓
**Control X-ray → Confirmation of stenting success**
↓
**Completion of the procedure → Monitoring in the ward**
↓
**Patient discharge → Outpatient follow-up**

Fig. 2. Hybrid technology model (simultaneous angiography and stenting)

This model is characterized by minimizing the time between diagnosis and treatment, reducing the number of procedures, which reduces stress for the patient, and increasing the accuracy of treatment through immediate monitoring of results.

The interdisciplinary interaction model (Fig. 3) reflects the interaction of specialists of various profiles in the management of a complex clinical case.

**A patient with multiple pathologies**
↓
**Cardiologist → Primary diagnosis and consultation**
↓
**Radiological → Imaging (MRI/CT scan)**
↓
**Surgeon → Assessment of the need for surgery**
↓
**Anesthesiologist → Preparation for anesthesia**
↓
**Intensive care specialist → Postoperative follow-up**
↓
**Therapist → Long-term follow-up and correction of therapy**

Fig. 3. The model of interdisciplinary interaction

This model is distinguished by a clear distribution of roles between specialists, ensuring an integrated approach to treatment, as well as minimizing risks through joint decision-making.

The model of introducing artificial intelligence into the process of diagnosis and treatment (Fig. 4) demonstrates the use of AI for data analysis, risk forecasting and treatment optimization.

**Data collection: ECG, MRI, laboratory tests**
↓
**AI data analysis → Pathology detection**
↓
**Risk prediction → Treatment recommendations**
↓
**Automatic operation planning → Intraoperative control**
↓
**Postoperative monitoring → Adjustment of treatment**

Fig. 4. The model of artificial intelligence implementation in the process of diagnosis and treatment

As part of the implementation of this model, it is possible to accelerate the process of data analysis and decision-making, improve the accuracy of diagnosis and forecasting, as well as personalize treatment based on patient data.

The model of bioengineering solutions in cardiology (Fig. 5) demonstrates the use of bioengineering technologies to repair or replace damaged heart tissues.

**Pathology detection: myocardial infarction, valve defect**

↓

**Development of biocompatible material → Bioprinting of tissues**

↓

**Implantation of an artificial valve or a section of the myocardium**

↓

**Monitoring of the implant function → Adjustment if necessary**

↓

**Restoring normal heart function**

Fig. 5. Model of bioengineering solutions in cardiology



The model provides an opportunity to restore heart function without using donor materials, reduce the risk of rejection due to biocompatible materials, and opens up new opportunities for the treatment of previously incurable diseases.

The above models clearly demonstrate the key stages of interaction between diagnostic and operational approaches, as well as the advantages of integrating modern technologies into cardiology. They help to systematize the treatment process, identify weaknesses and suggest ways to eliminate them. Such models can be used both for training medical personnel and for developing new treatment protocols, which contributes to improving the quality of medical care.

The interdisciplinary approach, therefore, promotes the introduction of innovative technologies and techniques into clinical practice[25]. For example, the use of hybrid operating rooms, where the possibilities of surgery and imaging are combined, requires close cooperation between specialists in various fields. Robotic systems, artificial intelligence and bioengineering developments are becoming more accessible thanks to the joint efforts of doctors, engineers and researchers.

In addition, an interdisciplinary approach helps to increase the level of professional competence of all participants in the process. Discussion of complex cases in consultations, exchange of experience and knowledge between specialists help to find optimal solutions for each patient, which is especially important in conditions of limited resources and the need to improve the effectiveness of treatment[26].

Thus, an interdisciplinary approach in cardiology is a fundamental principle that allows combining the efforts of specialists from different fields to achieve the best treatment results. Such cooperation not only improves the quality of medical care, but also promotes the development of new technologies and techniques, opening up new horizons in the fight against cardiovascular diseases.

The prospects for further development of technologies such as artificial intelligence, machine learning, and bioengineering open up new horizons in the field of diagnosis and treatment of cardiovascular diseases[27]. Such technologies have the potential not only to improve the accuracy and effectiveness of medical care, but also to radically change the approach to disease management, making it more personalized, predictable and accessible[28].

Artificial intelligence and machine learning methods are already being actively introduced into cardiology, offering revolutionary solutions for data analysis, process automation and decision support. AI can automate routine tasks such as analyzing laboratory data, documenting medical history, and even scheduling surgeries, which frees doctors from performing technical work, allowing them to focus on making key decisions[29].

Bioengineering is one of the most promising areas in the treatment of cardiovascular diseases. It combines advances in biology, medicine, and engineering to create innovative solutions that can repair or replace damaged tissues and organs. Bioprinting using stem cells and biocompatible materials makes it possible to create artificial heart tissues such as valves, vessels, or even sections of the myocardium. This opens up new possibilities for the treatment of patients with congenital heart defects or the consequences of a myocardial infarction.

Modern pacemakers, defibrillators, and artificial hearts are becoming more and more miniature, reliable, and "smart." Thanks to bioengineering, these devices can be integrated with AI systems, allowing them to adapt to the patient's condition in real time.

Nanotechnology makes it possible to create devices and drugs that act at the level of cells and molecules. For example, nanoparticles can deliver drugs directly to the affected areas of the heart, minimizing side effects. Gene therapy is becoming a real tool for the treatment of hereditary heart diseases such as cardiomyopathy or arrhythmias. Making changes to the DNA of heart cells can help restore their normal function[30].

One of the key trends of the future will be the integration of various technologies into a single ecosystem. For example, the combination of AI, bioengineering and telemedicine will create systems that will not only diagnose and treat diseases, but also monitor the condition of patients in real time. Such systems will be able to warn doctors about possible complications before they occur, which will significantly improve the quality of medical care.

Artificial intelligence, machine learning, and bioengineering technologies have enormous potential to expand the possibilities of diagnosis and treatment of cardiovascular diseases. They will make medicine more accurate, personalized and effective, as well as reduce treatment costs by automating processes and preventing complications. However, the implementation of these technologies requires careful regulation, ethical expertise, and training of specialists capable of working with new tools. The development of these areas will become the basis for creating the medicine of the future, where treatment will be based on a deep understanding of biological processes and the use of advanced technologies to correct them.

## Conclusions

The combination of diagnostic and surgical approaches in the treatment of cardiovascular diseases is a multidimensional field that continues to evolve through the introduction of advanced technologies and interdisciplinary collaboration. The considered integrated approach allows not only to improve the accuracy of diagnosis and the safety of treatment, but also to make medical care more accessible and personalized.

Modern diagnostic technologies such as MRI, CT, echocardiography and laboratory tests are the foundation for effective treatment of cardiovascular diseases (CVD). They make it possible to identify pathologies at an early stage, predict the risks of complications, and monitor the effectiveness of treatment. Diagnostics not only provides an accurate picture of the patient's condition, but also serves as the basis for making decisions about the need and type of surgical intervention.

The development of minimally invasive technologies such as coronary angioplasty, stenting, implantation of pacemakers and the use of robotic systems has significantly reduced the incidence of surgical interventions. Such methods can speed up patients' recovery, minimize the risk of complications, and make treatment accessible to a wider range of patients, including the elderly and people with severe concomitant diseases.

The successful combination of diagnostic and operative methods is becoming the standard of modern cardiology. Hybrid technologies that combine diagnosis and treatment within a single protocol (for example, simultaneous angiography and stenting) ensure high accuracy and safety of interventions. Intraoperative imaging and the use of AI complement these approaches, making them even more effective.

The management of complex clinical cases requires close cooperation between specialists of various profiles: cardiologists, surgeons, radiologists, anesthesiologists and other experts. The interdisciplinary approach allows for comprehensive data analysis, balanced decision-making, and optimization of the treatment process, which is especially important when working with patients with multiple concomitant diseases or rare forms of pathology.

Artificial intelligence, machine learning, and bioengineering are opening up new horizons in the diagnosis and treatment of CVD. AI is already being used to analyze medical images, predict risks, and personalize treatment. Bioengineering offers innovative solutions such as bioprinting of tissues, creation of artificial organs and gene therapy. Such technologies have the potential to significantly expand the capabilities of medicine and improve the quality of life of patients.

The combination of modern diagnostic and operational approaches contributes to improving the quality of medical care, reducing treatment costs and improving long-term prognosis for patients, which is especially important in the context of the growing prevalence of CVD and limited health resources.

The future of cardiology is linked to the further development of innovative technologies such as artificial intelligence, bioengineering and hybrid methods, which will open up new opportunities for the prevention, diagnosis and treatment of CVD, improving the quality of life of millions of patients worldwide.



## References

1. Ruetzler K, Khanna AK, Sessler DI. Myocardial injury after noncardiac surgery: preoperative, intraoperative, and postoperative aspects, implications, and directions. Anesth Analg. 2019.

2. Devereaux PJ, Szczeklik W. Myocardial injury after non-cardiac surgery: diagnosis and management. Eur Heart J. 2019.

3. Puelacher C, Lurati Buse G, Seeberger D, Sazgary L, Marbot S, Lampart A, Espinola J, Kindler C, Hammerer A, Seeberger E, et al; BASEL-PMI Investigators. Perioperative myocardial injury after noncardiac surgery: incidence, mortality, and characterization. Circulation. 2018;137:1221–1232.

4. Smilowitz NR, Redel-Traub G, Hausvater A, Armanious A, Nicholson J, Puelacher C, Berger JS. Myocardial injury after noncardiac surgery: a systematic review and meta-analysis. Cardiol Rev. 2019;27:267–273.

5. Smilowitz NR, Gupta N, Guo Y, Beckman JA, Bangalore S, Berger JS. Trends in cardiovascular risk factor and disease prevalence in patients undergoing non-cardiac surgery. Heart. 2018;104:1180–1186.

6. Grobben RB, van Waes JAR, Leiner T, Peelen LM, de Borst GJ, Vogely HC, Grobbee DE, Doevendans PA, van Klei WA, Nathoe HM; CHASE Investigators. Unexpected cardiac computed tomography findings in patients with postoperative myocardial injury. Anesth Analg. 2018;126:1462–1468.

7. Meershoek AJA, Leunissen TC, van Waes JAR, Klei WA, Huisman A, de Groot MCH, Hoefer IE, van Solinge WW, Moll FL, de Borst GJ. Reticulated platelets as predictor of myocardial injury and 30 day mortality after non-cardiac surgery. Eur J Vasc Endovasc Surg. 2020;59:309–318.

8. Duncan D, Sankar A, Beattie WS, Wijeysundera DN. Alpha-2 adrenergic agonists for the prevention of cardiac complications among adults undergoing surgery. Cochrane Database Syst Rev. 2018;3:CD004126.

9. Kodeboina M, Piayda K, Jenniskens I, Vyas P, Chen S, Pesigan RJ, et al. Challenges and Burdens in the Coronary Artery Disease Care Pathway for Patients Undergoing Percutaneous Coronary Intervention: A Contemporary Narrative Review. International Journal of Environmental Research and Public Health. 2023 Apr 25;20(9):5633.

10. Hammond MM, Everitt IK, Khan SS. New strategies and therapies for the prevention of heart failure in high-risk patients. Clinical Cardiology. 2022 Jun;45:S13-25.

11. Khalil H. Traditional and novel diagnostic biomarkers for acute myocardial infarction. The Egyptian Journal of Internal Medicine. 2022 Dec;34(1):87.

12. Hasnie A, Clarkson S, Hage FG. A novel cardiovascular risk assessment tool for the prediction of myocardial ischemia on imaging. Journal of Nuclear Cardiology. 2023 Feb;30(1):335-42.

13. Chung CT, Lee S, King E, Liu T, Armoundas AA, Bazoukis G, et al. Clinical significance, challenges and limitations in using artificial intelligence for electrocardiography-based diagnosis. International Journal of Arrhythmia. 2022 Oct 1;23(1):24.

14. Desjardins LC, Vohl MC. Precision Nutrition for Cardiovascular Disease Prevention. Lifestyle Genomics. 2023 Jan 30;16(1):73-82.

15. Perry AS, Dooley EE, Master H, Spartano NL, Brittain EL, Pettee Gabriel K. Physical activity over the lifecourse and cardiovascular disease. Circulation Research. 2023 Jun 9;132(12):1725-40.

16. Getz V, Munkhaugen J, Lie HC, Dammen T. Barriers and facilitators for smoking cessation in chronic smokers with atherosclerotic cardiovascular disease enrolled in a randomized intervention trial: A qualitative study. Frontiers in Psychology. 2023 Mar 22;14:1060701.

17. Giron N, Lim C, Vallini J, Hallar K. Moving toward improved access to medicines and health technologies for cardiovascular disease. Rev Panam Salud Publica. Rev Panam Salud Publica; 2023 Jun 12:47:e93.

18. Zwack CC, Haghani M, Hollings M, Zhang L, Gauci S, Gallagher R, et al. The evolution of digital health technologies in cardiovascular disease research. npj Digital Medicine. 2023 Jan 3;6(1):1-11.

19. Ahmad SM, Ahmed NM. Classification based on event in survival machine learning analysis of cardiovascular disease cohort. BMC Cardiovasc Disord. 2023 Jun 20;23(1):310.

20. Wang Z, Peng J. The predictive value of the nomogram model of clinical risk factors for ischemia–reperfusion injury after primary percutaneous coronary intervention. Scientific Reports. 2023 Mar 28;13(1):5084.

21. Robbins BT, Howington GT, Swafford K, Zummer J, Woolum JA. Advancements in the management of acute ischemic stroke: A narrative review. Journal of the American College of Emergency Physicians Open. 2023 Feb;4(1):e12896.

22. Chen S, Schmidt B, Chun JK. Pulmonary veins isolation using cryoballoon and pulsed field ablation for atrial fibrillation: practical techniques in variable scenarios. International Journal of Arrhythmia. 2023 Dec;24(1):1-9.

23. Sethi Y, Patel N, Kaka N, Kaiwan O, Kar J, Moinuddin A, et al. Precision Medicine and the future of Cardiovascular Diseases: A Clinically Oriented Comprehensive Review. Journal of Clinical Medicine. 2023 Feb 23;12(5):1799.

24. Al Ahdal A, Rakhra M, Rajendran RR, Arslan F, Khder MA, Patel B, et al. Monitoring Cardiovascular Problems in Heart Patients Using Machine Learning. Journal of Healthcare Engineering. 2023 Feb 8;2023.

25. Moradi SZ, Jalili F, Hoseinkhani Z, Mansouri K. Regenerative Medicine and Angiogenesis; Focused on Cardiovascular Disease. Advanced Pharmaceutical Bulletin. 2022 Aug;12(4):686.

26. Park M, Song R, Ju K, Shin JC, Seo J, Fan X, et al. Effects of Tai Chi and Qigong on cognitive and physical functions in older adults: systematic review, meta-analysis, and meta-regression of randomized clinical trials. BMC Geriatrics. 2023 Jun 6;23(1):352.

27. Kharlamov A, Lamberts M. Digital medicine: the next big leap advancing cardiovascular science. BMC Cardiovascular Disorders. 2023 Jan 17;23(1):30.

28. Rurik JG, Aghajanian H, Epstein JA. Immune cells and immunotherapy for cardiac injury and repair. Circulation Research. 2021 May 28;128(11):1766-79.

29. Smith BR, Edelman ER. Nanomedicines for cardiovascular disease. Nature Cardiovascular Research. 2023 Apr;2(4):351-67.

30. Yang F, Xue J, Wang G, Diao Q. Nanoparticle-based drug delivery systems for the treatment of cardiovascular diseases. Frontiers in Pharmacology. 2022 Sep 12;13:999404.