

Original article

Remote Cardiac Monitoring and Russian Social Policy: Past and Present

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Abstract: Relevance: Remote cardiac monitoring is currently increasingly important, which is due to the development of technology, the growing interest on the part of patients and the healthcare system as a whole, and the creation of a functioning remote cardiac monitoring system integrated into the public healthcare system. With regard to Russia, it is crucial to investigate the features of the development of cardiac monitoring devices and the current state of the latter. At the same time, it is worth noting the lack of studies that examine the availability of mobile devices and their integration into the healthcare system in the early 2020s.

Objective: To investigate the development of remote cardiac monitoring devices in Russia in the context of socially important problems of providing medical care and preventing diseases, and the possibility of their use in the public healthcare system, taking into account the current state of technology, the characteristics of the market for wearable cardiac monitoring devices and their availability to patients in Russia.

Material and methods: The main method employed by us was a comprehensive analysis of the technical characteristics, availability for purchase, and reliability of the measurements performed by mobile remote cardiac monitoring devices available on the Russian market at the beginning of 2022. In addition, the article presents a comparison of the prevalence of remote cardiac monitoring devices in Russia, the Asia-Pacific region, the USA and Europe.

Results: In the second half of the 20th century, remote medical monitoring was used mainly in extreme circumstances when the direct participation of doctors was impossible or very problematic. However, at the turn of the 21st century, the development of technology and healthcare system, as well as the attitude of the population to their health, triggered a change in the approach to remote monitoring and diagnosing diseases, thereby putting the task of increasing the effectiveness of prevention, diagnosis and treatment of various ailments, including cardiovascular diseases, in the foreground of routine clinical practice. New generations of remote monitoring devices are becoming more effective, and their measurements are as accurate as possible. However, a study of the devices presented on the Russian market shows that each developer creates an individual closed 'ecosystem' that is not connected to the healthcare system. In this regard, the task of contemporary healthcare is the full integration of existing 'ecosystems' with available electronic medical records, along with spreading this practice to all regions of Russia. The solution to this problem is largely determined by the involvement of the state; it should be part of social policy in the healthcare sector.

Conclusion: The development of remote cardiac monitoring in Russia corresponds to the general global trends in the growth of the prevalence of wearable devices among patients with cardiovascular diseases. At the same time, one of the pressing issues remains the technical and legal feasibility of integrating the services of different manufacturers of cardiac monitoring devices into the state healthcare system.

Keywords: remote cardiac monitoring, cardiac monitoring devices, cardiovascular diseases, healthcare system, Russian social policy.

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Introduction

The task of providing timely high-quality medical care was always faced by the healthcare system. The solutions largely depended not only on the achievements of medical science, but also on the entire range of organizational and technical factors, among which the technologies of information transmission and processing ranked high. The digitalization of medicine and healthcare system has become crucial in the development of contemporary society, and one of the largest expenditure items in

national budgets worldwide [1]. Innovative technologies related to the development of artificial intelligence (AI), big data, and the Internet of Things have come to the aid of doctors and patients. At the same time, an important issue is the mistrust on the part of many people to medical institutions (about 30-40% according to various studies) [2-5]. The latter is preserved in collective memory and cannot be overcome in a short time. For many people, attending medical institutions is associated either with experiencing stress and even fear when visiting a doctor [2], or (in

conditions of paid medical services) with the costs unaffordable for part of the population [6]. Hence, the visit to a physician is postponed until it is no longer possible to avoid it [6, 7]. The lack of desire to undergo regular medical examinations and subtle symptoms in the early stages of many serious diseases lead to the situation when many Russian residents do not know about their predisposition to certain illnesses and the risks of their development. Consequently, they do not have the opportunity to identify them in time and take the necessary measures. Besides, the spread of high-quality health care to remote areas of the country is typically slower than the spread of the available Internet. The combination of the low prevalence of digital services in medicine and continuing negative attitude of people towards medical institutions emphasizes the need to develop either face-to-face patient care or telemedicine. In both cases, two major factors can be distinguished: the availability of high-tech devices (given the financial ability of patients to purchase such medical services), and the willingness to use them. As for remote medical monitoring, an additional important condition is the development of relevant services.

The introduction of information and communication tools into the healthcare practice and the development of telemedicine determined the widespread use of mobile devices for recording various parameters of the human body. The collection of new data, along with digitization of existing patient records, determines the need to create an electronic infrastructure for storing patient data. Mobile devices can be used to collect and store a variety of health-related patient data into health information systems. Such data are collected from patients and then transferred to the appropriate healthcare professionals [8]. Numerous researchers are working on the problems of remote cardiac monitoring development. Hence, substantial experience has been accumulated in solving organizational and technical issues related to the possibility of using remote cardiac monitoring devices both for independent diagnostics and for their integration into the healthcare system. Technical characteristics and software of such devices are improving annually. However, many problems remain not fully resolved, such as: organizational and technical difficulties related to the creation of a unified system for collecting and storing data on the health status of patients within the healthcare system and integrating devices from different manufacturers into this system; ethical and legal issues related to the consent of patients regarding storing and using information on their health status and the safety of these data; organizational and financial issues related to training the personnel of medical institutions in using relevant software and their subsequent remuneration for additional job responsibilities, etc. [9, 10].

The objective of our study was to examine the development of remote cardiac monitoring devices in Russia in the context of socially significant problems they could resolve in providing medical care and preventing diseases, along with the possibility of their use in the public health system, taking into account the current state of technology, the characteristics of the market for wearable cardiac monitoring devices and the availability of the latter to patients in Russia.

The novelty of this study lies in the analysis of the current state of remote cardiac monitoring in Russia as part of the telemedicine development in the context of ongoing social policy. Specifically, we discuss below the availability and technological features of wearable healthcare devices presented on the Russian market. This article analyzes both the achievements and problematic

issues, including the lack of integration of devices into the unified e-health system.

Material and Methods

Our review includes the following three sections.

The first section is dedicated to a retrospective analysis of remote cardiac monitoring in Russia according to the tasks that the state and society faced in the second half of the 20th century. Based primarily on Soviet and Russian studies, this section reflects the history of the development of technology and devices used in medical practice prior to the widespread use of mobile devices.

The second section is based on a review of wearable remote cardiac monitoring products on the market available for over-the-counter purchase by patients, as well as various developments currently implemented in medical institutions. We used the following criteria to select mobile remote cardiac monitoring devices for our review: their presence on the market at the beginning of 2022, their availability for purchase by Russian nationals at the beginning of 2022, and availability of the information on their cost. The sources of information included the official websites of the developers, as well as trading platforms where these devices were advertised. For those devices for which studies were conducted on the accuracy of their readings, the corresponding reviews and results were presented in the eLibrary.ru and PubMed databases. Additionally, we reviewed documents reflecting government policy regarding telemedicine. The main focus of this review is on the availability of wearable remote cardiac monitoring devices and the possibility of using them in the public healthcare system in Russia.

The third section of our review includes a comparative analysis of the situation with remote cardiac monitoring devices in Russia vs. other countries/regions. The analysis involves comparing the commonness of remote cardiac monitoring devices in Russia, the Asia-Pacific region, the USA and Europe. The sources were statistical data presented in official information resources. Additionally, we used data from published sources presented in the PubMed library to identify the specifics of individual regions. Among the aspects of telemedicine and cardiac monitoring, we considered the maturity of the relevant markets and the sociocultural setting, including the ability of various population groups to use remote cardiac monitoring devices.

Results

Development of telemedicine and remote cardiac monitoring in Russia: Historical aspects

Reviewing the current state of telemedicine and the potential of remote monitoring in the healthcare system, we should note the social role that they played at different stages of their development. The active introduction of methods for remote processing of information on the state of the cardiovascular system took place in the USSR in the second half of the 20th century. In the early 1960s, the miniaturization of bioradiotelemetric devices has occurred, as a result of which the possibility of a wide clinical application of this technology emerged [11, 12]. Since the late 1960s, various studies and implementation of a wide variety of bioradiotelemetric systems were carried out in the USSR [13, 14]. The teams that worked in clinical and research institutions of Sverdlovsk (currently, Yekaterinburg) under the supervision of V.V. Rosenblat [14], L.S. Dombrovsky and R.V.

Unzhin [15] have developed and implemented over 50 biotelemetric devices and their modifications in a short period of time. These devices included radio heart rate monitor, radio pneumographs, radio spirometers, combination radiotelemetry systems and transmitting devices. During this historical period, the approaches to designing and manufacturing multichannel systems for remote registration of measurements were developed [16-18]. The majority of developed devices were used in sports, experimental medicine, cardiology, orthopedics, pulmonology, as well as in the study and treatment of occupational pathology [17-21]. The use of the *Volna* cardiac telemetry system (manufactured since 1974) and its analogs made it possible to perform analog transmission of electrocardiograms (ECG). Although the number of ECGs received by some centers amounted to hundreds of thousands, this vast experience remained not fully systematized [22].

Since the 1960s, telephone communication and services based on it (fax, teletype, etc.) were widely used all over the world for the transmission of medical information and telemetry data [23, 24]. In 1972, one of the first transtelephonic ECG centers was established in Saratov (USSR) on the initiative of Professor Emmanuil Sh. Halfen, the founder and first director of Saratov Research Institute for Cardiology.

During six years of its functioning, over 210 thousand remote consultations were carried out by its employees [23,25]. Later on, similar remote diagnostics centers were established in many cities of the Soviet Union. Transtelephonic data transmission were most widely used in electrocardiography [23, 26]. Some studies have shown a decrease in the levels of mortality and lethality as a result of using this type of telemedicine systems [27-29]. In the early 1970s, the clinical and diagnostic efficacy of telecardiology has been convincingly demonstrated [30, 31].

In 1970, during the 15th Soviet Antarctic Expedition, the first experimental transmission of a series of ECG was performed from the Mirny Observatory to the city of Leningrad [32, 33]. Therefore, 1970 can be considered the starting point of the introduction of telemedicine tools and methods into the medical practice of polar research in the Antarctic [34].

In the second half of the 20th century, the versatility of applying telemedicine technologies (including in the field of cardiology) were largely due to the tasks of disease prevention and provision of urgent medical care to people working in extreme conditions, such as outer space, Arctic, and Antarctic, or suffering from natural disasters, especially when direct participation of doctors was challenging.

As a result of the rapid development of computer manufacturing industry and the globalization of the Internet, telemedicine technology was used in most countries worldwide. In 2005, the World Health Organization (WHO) adopted the resolution WHA58.28 *eHealth*, sensibly regulating the use of telemedicine for the first time in history. F. Koehler et al. noted that the use of telemedicine technologies in chronic heart failure could reduce mortality by 30-35% [35].

For example, in the second half of the 20th century, remote medical monitoring was developed chiefly in situations where the direct participation of medical professionals was barely possible, if at all. However, at the very beginning of the 21st century, the development of technology and healthcare systems, along with the attitude of a population to their health, determined a change in the approach to remote monitoring and diagnosis of diseases:

the task of increasing the effectiveness of disease prevention, diagnosis and treatment of various ailments, including cardiovascular diseases, was placed in the foreground of routine clinical practice.

Digitalization of the healthcare system and development of remote cardiac monitoring

One of the conditions for the spread of remote health monitoring technologies is the development of a single information platform connecting all medical institutions and allowing remote interactions between doctors and patients.

Although, Russia has significant potential in creation and application of telemedicine, it is not a pioneer in the development of telemedicine systems [36-40]. The spread of digital technologies determined the development of the *Digital Health Care* program in the country, which actually has become one of the key elements of the *Digital Economy* program. In her article, Yu. Morozova makes the point that the healthcare system needs to create innovative digital healthcare complexes based on novel technologies and management methods meeting current conditions [41]. The domestic health care faces the task of forming telemedicine queuing systems at the regional and federal levels.

Remote cardiac monitoring technologies are developing in the context of the general development of telemedicine systems, albeit having their own characteristic features. The major task of remote cardiac monitoring is the implementation of continuous monitoring of cardiac activity. In practice, there are situations when symptoms are vague and cannot be detected by standard methods. In such cases, there is a need for situational ECG recording at the time of the complaint occurrence. It is also important to monitor favorable or undesirable effects of prescribed medicines. Remote cardiac monitoring devices are designed to solve these problems. With the help of such devices, the patient can independently record an ECG and other cardiac health indicators at the right time and at the right frequency [42].

The problem of using methods and technologies of remote cardiac monitoring is widely discussed by scientists and experts. For instance, the capabilities of remote health monitoring systems in patients with cardiac pathologies has become the main topic of the open discussion platform, *Digital Health*, which took place on April 21, 2016, at the MEDSI Clinical Diagnostics Center in Krasnaya Presnya [43]. The study of oncological patients by E.I. Emelina et al. demonstrated that extensive introduction of continuous remote cardiac monitoring techniques into clinical practice improved the quality of life in patients, along with increasing their life expectancy [44]. Favorable outcomes of using remote cardiac monitoring were confirmed by other researchers as well [45].

The need to expand the use of remote monitoring devices in cardiology is also determined by the persistence of the incidence of coronavirus (COVID-19), which has significantly increased the number of cardiovascular complications and arrhythmias in patients [46]. During the spread of the pandemic, patients at risk were recommended continuous cardiac monitoring. However, the availability of hospital beds with telemetry capabilities was insufficient both in Russia and abroad [47], and therefore the role of the remote method of interaction between a doctor and a patient in an epidemic situation has increased. The conditions of the pandemic have shown that digital health technologies, in particular telemonitoring of blood pressure, could become the

only way to effectively and safely monitor the well-being of patients with chronic diseases [48].

The development of technology and healthcare system, along with altered attitude of the population to their health, triggered a transformation in the approach to cardiac monitoring, putting the task of increasing the effectiveness of prevention, diagnosis and treatment of cardiovascular diseases in the foreground, with a more efficient use of health care resources and resources of the patients.

Modern technologies of cardiac monitoring are currently used more widely, since both medical professionals and patients are interested in them. However, the goals, major tasks, and priority areas for the development of health care in the Russian Federation set out in the *Strategies for the Development of Health Care in the Russian Federation for the Period Up to 2025* do not include telemedicine or remote health monitoring, even though the document pays close attention to the development and improvement of functioning of a unified nationwide information system in the field of healthcare, along with the development of a unified digital complex in healthcare based on it [49].

Contemporary domestic and foreign devices for remote cardiac monitoring

Lately, more attention is paid to the timely provision of specialized medical care and the possibility of remote monitoring of the patient's condition by the attending physician. Modern technologies for recording patient health data are represented by portable automatic devices (external and implantable) for inpatient and outpatient use. They provide automatic recording of cardiac events and can be activated by the patient when any symptoms appear.

The development of contemporary remote cardiac monitoring is presented in various domestic and foreign projects. Novel devices have varying accuracy of measurements [50]. The use of external autonomous devices has become the most widespread.

There are two main types of contemporary devices available on the Russian market: 1) in the form of separate modules, placed on the chest one way or another, with or without leads; 2) in the form of plates that you need to touch with your fingers to measure readings ([Table 1](#), [Figure 1](#)). However, the design of devices in both the first group and the second group has certain characteristics. E.g., The *CardioPatrol* device, which was developed in St. Petersburg, is presented in the form of a miniature monitor that transmits a three-channel ECG signal (connection is possible according to the Nebh scheme or the Einthoven scheme). *QardioCore* is a device for real-time ECG recording in the form of a special tape with sensors surrounding the human torso [51]. At the same time, *QardioCore* is positioned as the world's first wearable wireless heart health monitoring device without stickers and suction cups: the device is attached to the chest with a strap. The *ECG Dongle* [52] is a small cardio flash drive that connects to a mobile phone by the USB cable. The *OPEKA-04* pectoral mobile complex is also based on a wearable module in the form of a bracelet [53] (as of 2025, there are no public data on the commercial availability of this device).

Devices that take readings via finger touch are available as plates integrated with a smartphone (*CardioQVARK* [54]), and also as separate plates with two (*AliveCor KardiaMobile* ECG monitor) or six contacts (*KardiaMobile AliveCor 6L*). *AliveCor KardiaMobile* ECG monitor is placed on the back of the smartphone, while

KardiaMobile AliveCor 6L presumes applying the device to the left ankle or a knee.

Accordingly, all devices placed on the chest are designed for continuous wear and have the ability to take readings continuously. The autonomy of rechargeable devices (*CardioPatrol*, *QardioCore*) is about 24 hours. The operating time of devices powered by batteries (*AliveCor KardiaMobile* ECG monitor, *KardiaMobile AliveCor 6L*) is not specified. The operation of the *ECG Dongle* depends on the battery level of the smartphone. The *CardioQVARK* device has a claimed battery life of up to 30 days.

All devices are designed to record an ECG, diagnose important events in the functioning of the cardiovascular system, and assess the general health condition of their user. It is worth noting that most devices, when using the relevant applications on a smartphone, automatically send data to a server or to cloud storage. For instance, diagnostic data obtained by the *CardioPatrol* system can be transmitted, if necessary, to a server, to which specialists have access [55]. The data received by the *ECG Dongle* cardio flash drive are sent to the cloud service, where the ECG is decoded. After recording an ECG, the *CardioCloud* service allows obtaining an automatic analysis in 5 minutes, as well as an ECG analysis by a clinician in 15 minutes by e-mail [56]. However, the subscription costs 99 rubles per month. When using the *QardioCore* device, it becomes possible to obtain analytics only after its owner becomes a client of a doctor who is registered with the *QardioMD* system [51]. Using the *CardioQVARK* monitor, doctors can access data remotely in the virtual Doctor's Office or in the Medical Information System (MIS) via API (Application Programming Interface) [54]. The *OPEKA* (meaning "guardianship") complex transmits information to the MIS continuously or at specified intervals, and these data can be viewed by the attending physician and the district doctor [57]. If the state of health deteriorates, the patient can activate the *panic button*. After receiving an alarm call at the call center, an operator will contact the owner of the bracelet from the intercom unit, and an SMS notification will be sent to the patient's relative about the alarm. Therefore, solely *CardioQVARK* and *OPEKA* are integrated with MIS.

It should be noted that remote interaction with a medical specialist is not specified for *AliveCor KardiaMobile* ECG monitor and *KardiaMobile AliveCor 6L* devices in Russia. *AliveCor* smartphone application is only available for Google Play and AppStore in the USA, Canada, UK, Ireland, India and Australia. Hence, for their use in Russia, it is necessary to create an American account in addition to the existing Russian account [58].

Arrhythmia monitoring using implantable devices is also gradually gaining popularity in Russia, having already become the gold standard in European countries and the USA, where it is included in the recommendations of medical associations of cardiologists [59]. In order for these methods to become regularly used, it is necessary to include them in the recommendations for the diagnosis of arrhythmias [59]. The so-called *household* (not professional) devices available on the market correspond to the current trend of the patient's trust in the role of technology in diagnosing health problems, but often do not justify themselves and even mislead their users regarding individual parameters, because their sensitivity and specificity do not reach the levels that would allow them to be considered as *professional medical devices*.

Currently, continuous and remote long-term monitoring of heart rate is possible by means of implantable loop recorders, which are a plug-in heart monitor in the form of a small device that is implanted directly under the skin [60]. A number of devices have the ability to wirelessly transmit data to home transmitters, which in turn transmit data to the doctor via cloud computing interfaces, allowing remote monitoring of the patient's condition. Such systems are widely used worldwide; they are approved for routine clinical practice in the United States, and are also used for remote monitoring of patients in Europe and Russia, where their introduction into medical practice is gaining momentum [59].

For example, in present-day Russia and throughout the world, mobile devices that can detect cardiovascular system disorders are becoming more and more common. For numerous mobile applications offering advanced solutions to the problem,

undiagnosed atrial fibrillation is the main goal, whereas the detection of recurrent episodes of atrial fibrillation is a secondary objective. A variety of remote cardiac monitoring devices allows consumers choosing the most convenient of them, acceptable in terms of their quality, functionality and cost. Simultaneously, such diversity creates certain difficulties for the healthcare system regarding integrating the obtained data into a single information system, including an electronic medical records system with a full personal medical information related to all types of medical care received by the patient at healthcare facilities. This information system constitutes a multifunctional basis for long-term accumulation and storage of information about what happened to patients or was done for their recovery in one or another period of their lives [61] ([Figure 2](#)).

Table 1. Comparative characteristics of remote cardiac monitoring devices available for over-the-counter sales in Russia

Device name	CardioPatrol	ECG Dongle	QardioCore	CardioQVARK	OPEKA-04	AliveCor Kardia Mobile ECG Monitor	KardiaMobile AliveCor 6L
Device type	Cardiograph in conjunction with a smartphone	Cardiac USB drive with electrodes in conjunction with a smartphone	Chest strap	Plate with 2 electrodes	Module placed on the body	Plate with 2 electrodes	Plate with 6 contacts
Device placement	Chest	Chest	Chest	Two fingers are placed on the sensors	Chest	Placed on the back of the smartphone, two fingers placed to the sensor	Placed on the left ankle or knee, two fingers placed on the sensor
Autonomy	Over 24 hours	No data available	24 hours	Up to 30 days	No data available	No data available	No data available
Diagnostics	Three-channel ECG signal (connection according to the Nebh scheme or according to the Einthoven scheme)	ECG 6, 6 leads	ECG, pulse	ECG, heart rhythms. Calculation of RR, P, PR, QRS, QT, QTc; detection of arrhythmia; calculation of heart rate variability parameters	Automated ECG analysis, detection of arrhythmias and their classification, heart rate variability analysis	Two-finger electrodes. ECG, bradycardia, tachycardia and normal heart rhythms	Recording 6 indicators. ECG, detection of atrial fibrillation, bradycardia, and tachycardia
Information for a patient	In the form of danger signals	Stress level, Automated ECG analysis	ECG, physical activity and skin temperature	ECG recording, diary of blood pressure and blood glucose levels	Generating reporting forms, including premedical health assessment	ECG analysis, information in the application	ECG analysis, information in the application
Charger	Wireless charging according to the Qi standard for an hour	No battery. Works from a Smartphone via an OTG cable	USB cable	MicroUSB cable	No data available	Battery type: CR2016	Battery type: CR2016
Wearing time	It is possible to wear the device constantly	Depending on the situation	It is possible to wear the device constantly	Depending on the situation	It is possible to wear the device constantly	Depending on the situation	Depending on the situation
Type of pairing	Pairing with a smartphone	Pairing with a smartphone	Pairing with a smartphone (iPhone)	Pairing with a smartphone	Pairing with a smartphone/ radio communication bracelet OPEKA-04	Pairing with a smartphone	Pairing with a smartphone
Information storage time (memory capacity)	180 days	No data available	No data available	No data available	No data available	No data available	No data available
Transferring data to the server	Automatically or upon user's request	Upon user's request. Transfer of data to the cardio cloud service	Saving to the cloud. Can be sent to the doctor	Transfer of data to the virtual Doctor's Office or to the Medical Information System via Application Programming Interface	Sending to the cloud	Saving in the application	Saving in the application



Figure 1. Images of remote cardiac monitoring devices available for over-the-counter sales in Russia.

However, the development of the Unified State Information System in the Field of Healthcare (USISH) is complicated by the fact that each Russian region initiated independent informatization of the healthcare system, starting with purchasing the equipment and software, including forms of documents and methods of their maintenance. Consequently, at the moment, there is no opportunity to combine them into a single system. E.g., mobile health (mHealth) and eHealth technologies (remote cardiac monitoring, an online patient cabinet, offline clinics, and the principles of work of an IT doctor) are currently used to prevent chronic noncommunicable diseases in the Tver Oblast [62].

Discussion

Comparing the development of telemedicine in Russia vs. other countries, we should point out that there is a general trend towards an increase in its prevalence and use for the diagnosis and treatment of various diseases. According to an analysis by H. Ndwabe et al., telemedicine has become widespread in North America, primarily in the United States and Canada, and its use is increasing in Europe, with countries such as the United Kingdom, Norway, Sweden, Denmark, Germany, and Italy at the forefront of telemedicine and telehealth adoption [63]. Telemedicine is gaining momentum in Asia, especially in China, Japan and South Korea. E.g., in China, it is used to address problems of access to health care in rural areas [63]. In Japan, telehealth is used to provide health care services to the elderly population. H. Ndwabe et al. stated that 27 of the 77 countries represented in their review demonstrated advanced telemedicine acceptance [63]. They classified Russia as an advanced country in this regard as well [63].

By assessing the extent of distribution of remote cardiac monitoring devices, it is possible to compare the size of their markets on a country-to-country basis. For example, in North America, such market amounted to \$1.57 billion in 2023, making North America the ultimate leader with the largest world market

share (at 46%). At the same time, the Asia-Pacific region is becoming the fastest growing region in the world market. The United States market size of remote cardiac monitoring was estimated in 2023 at \$1.10 billion [64]. The U.S. and Canada are at the forefront of technology innovation, with a strong 'ecosystem' of healthcare startups, research institutions and industry leaders constantly pushing the boundaries of remote monitoring technology. Besides, the regulatory documentation framework in North America, particularly in the United States, supports the development and implementation of digital health technologies [64].

The European market is also expanding. The introduction of cutting-edge devices such as the HUAWEI ECG app and MicroPort CRM pacemakers highlights current technological advancements. The UK is expected to have a significant share in the cardiac monitoring market due to its advanced healthcare infrastructure, government initiatives and growing number of cardiovascular diseases. In August 2022, NHS England Blood Pressure (BP) Monitoring @Home initiative was launched to support heart failure patients with the tools they need to remotely monitor their condition at home [65]. The use of monitoring devices for heart arrhythmia in France is also expanding due to increased alcohol consumption in the country and the growing supply of remote cardiac monitoring devices. In June 2021, eDevice SA, a medical technology company specializing in telemedicine and remote patient monitoring solutions, took over the commercialization of TwoCan Pulse™ by Boston Scientific in France. eDevice is the developer of this innovative telecardiology monitoring system on the French market. TwoCan Pulse™ is designed for remote monitoring of patients with symptoms of potential heart failure [66].

The development of healthcare infrastructure and the introduction of contemporary technology in other countries (such as India, Japan and China) stimulates the creation of remote cardiac monitoring systems. Governments and healthcare

organizations are increasingly investing in telemedicine and remote monitoring to improve access to healthcare, especially in rural and underserved areas. In addition, Asian countries have various opportunities and different needs to improve health of the population, thereby challenging public policy to reduce health care inequalities [67].

Market access requirements (e.g., approval by the Food and Drug Administration in the USA or CE marking through the procedure of conformity assessment under the 2017/745 European Medical Device Regulation), remuneration, and data privacy/security may vary substantially across countries and regions [68]. These requirements are largely determined by the specifics of the remote cardiac monitoring device and its intended use, the technology used, the risks and benefits associated with its use, and the data it processes. The current state of regulatory and legal aspects for smart wearable devices implies that the market for wearable cardiac monitoring devices will expand further in the near future, as wearables are increasingly used as a means of collecting data on which clinical predictive models can be based and trained [69, 70].

Implantable devices have long been the primary focus of research, and although the validity of their data remains controversial, their use is rapidly expanding, enabling health care providers to respond quickly to deteriorating health condition of patients [71]. However, since recently, there have been increasing prospects for improving the diagnostic accuracy of wearable devices, promoting their transformation from screening and preliminary diagnostic tools into full-fledged diagnostic devices.

International technological developments have brought to the forefront a wider range of various smart wearable devices than what is available in the Russian market. Technological advances have made it possible to integrate heart rate monitors into numerous commercially available wearable devices ranging from smart accessories to sensors embedded in clothes and shoes. Heart rate sensors can also be embedded in accessories such as rings, necklaces, earphones, chest straps, and glasses [72]. Most commercially available wearable devices are capable of

continuous monitoring for several days, provided they have a sufficiently long-lasting battery [73].

However, the wide variety and significant differences in the type and quality of information they provide makes their integration into routine clinical practice and appropriate use by practitioners rather difficult [72]. Along with signal loss, disadvantages of wearable devices also include false positive signals in case of smart watches, side effects to adhesive monitors, and a complex user interface for patches. In some cases, it is necessary to remove the device and transfer it to the manufacturer for data collection and analysis (ZioPatch and CardioSTAT devices). Embedding electronics in fabric can result in bulky and inflexible garments [67]. The ideal wearable heart rate monitoring device should be easy to use even for elderly patients without advanced technology skills. Also, it should provide continuous and accurate real-time cardiac monitoring and should not interfere with daily routine activities. In general, adapting digital health tools to local cultural and world outlook contexts [74, 75] with an emphasis on user-centered interfaces may facilitate better acceptance of remote cardiac monitoring devices [76].

The major obstacle for expansion of the telemedicine use is the poor development of infrastructure. There are problems with the distribution of remote cardiac monitoring devices associated with technological limitations of access to the Internet [77] and the corresponding poor capability to transfer data to the server, usually due to the low availability of mobile Internet or Wi-Fi networks. The sociocultural limitation of the use of remote cardiac monitoring devices is their affordability, as well as insufficient understanding on the part of potential users of the purpose of these devices and inability to operate them. E.g., an important problem that manifests itself not only in Russia, but in other countries as well, is the pricing and availability of wearable remote cardiac monitoring devices. Researchers noted that the involvement of public and private insurance providers in reimbursement for data transfers remains an open question [78]. Another obstacle to the widespread use of wearable devices is the accuracy of measuring various parameters of the cardiovascular system functioning and the battery life duration.

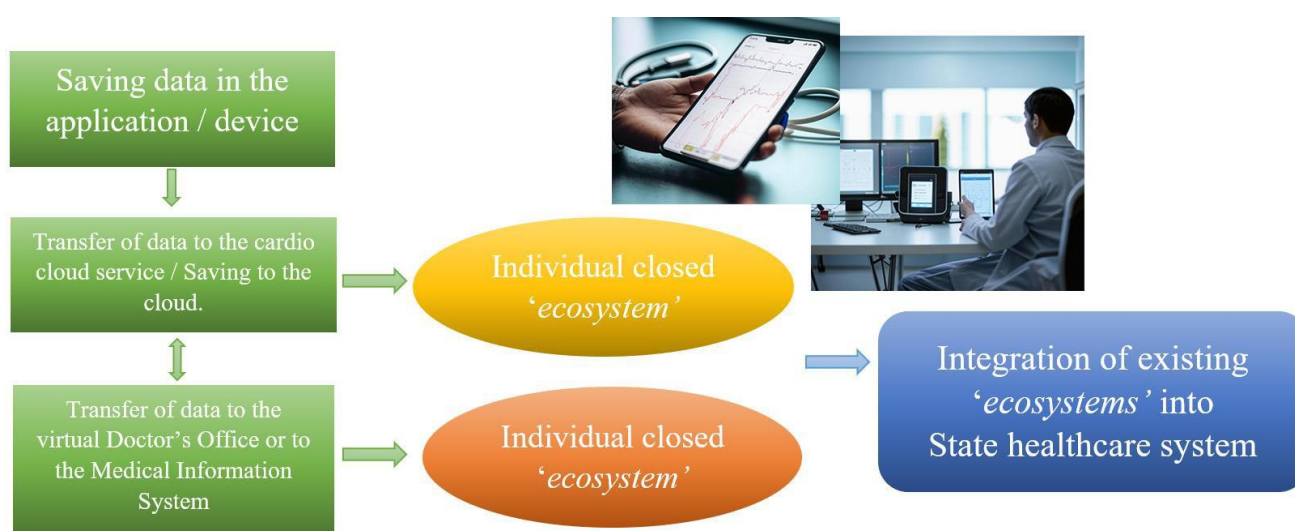


Figure 2. Modern trends in the development of remote cardiac monitoring.

Adherence to remote monitoring varies widely depending on social and individual factors that remain poorly understood [79]. In the United States, researchers noted that the most vulnerable population groups are women and African Americans [80]. Inequalities in access to health care and in health care outcomes persist among vulnerable population groups, mainly those with sociodemographic risk factors [81]. Significant differences in adherence to telemonitoring were established between races, ethnicities, and presence/absence of neuropsychiatric comorbidities [82]. However, as shown by the Russian data, one of the reasons for differences may be insufficient emphasis on expanding the use of remote cardiac monitoring devices within the framework of public policy in the health care system. Similar problems exist in other countries. For example, in Israel, remote monitoring was occasionally offered to only a small fraction of patients [83].

A promising direction for the development of remote cardiac monitoring devices may be the combination of AI algorithms with wearable devices, which may increase the reliability of their measurements and provide predictive capabilities for subclinical heart diseases [84]. Advances in deep learning technology and its use in diagnostic algorithms can further improve diagnostic accuracy [85]. Another direction for improving remote monitoring devices could be complex solutions that can continuously and simultaneously monitor multiple biophysical parameters (e.g., oxygen saturation, heart rate). M.H. McGillion et al. classified them as devices for continuous multiparameter remote automated monitoring (CM-RAM) [86].

Integrated systems of data processing can lead to improved patient management, personalized healthcare interventions, and more effective use of healthcare resources [87]. At the same time, it is important to have clear legal standards and the ethical framework within which personal data are collected and processed [88]. An important area of focus is the development of an international legal framework allowing health care providers to deliver services across jurisdictions and countries [89]. In general, the focus of healthcare startups has recently shifted toward AI-based personalized care via smartphones, including digital therapeutics and wearable technology innovations [90].

J. Zhang et al. noted that telemedicine has a great impact on the development of a comprehensive national health care system in China [91]. Immediate exchange of medical information effectively mitigates the situation of serious information imbalance between doctors and patients.

Hence, wearable devices are becoming the new reality in monitoring and treating cardiovascular diseases worldwide. To ensure their effective use as medical devices, we must address numerous challenges, such as signal quality, availability of Internet connection, battery life limitations, suboptimal diagnostic accuracy, as well as data security and storage, which requires input from both qualifying scientists and government in resolving these issues. However, one of the most important issues in the field of using remote cardiac monitoring devices is to arrange who and how will pay for the purchase and continuous use of such devices.

Remote cardiac monitoring is in demand and its use gradually expands in the healthcare system, albeit acting as a secondary technique to traditional methods of cardiac monitoring. It helps providing patients with professional medical supervision, conducting more comprehensive diagnostics, and evaluating the effectiveness of applied therapeutic treatment. Remote cardiac

monitoring technologies are suitable for medical institutions (hospitals, polyclinics, specialized medical offices) and sanitarium-type institutions. They can be adapted to regional platforms and projects for the transformation, development and modernization of the infrastructure of territorial medical associations. Besides, contemporary digital devices increase the efficacy of medical care via enabling the patient to take necessary readings at home, transfer them to the MIS, and receive a remote consultation from a doctor.

The advantages of remote cardiac monitoring can be identified both for medical institutions and for the patients. The healthcare system has the opportunity to reduce the costs and expenditure of medical personnel labor by reducing both the length of a hospital stay and the use of hospital beds. The attending physician has the opportunity to remotely monitor the patient's health and compliance with treatment recommendations. An indirect positive consequence could be an increase in the reputation and image of a medical institution. Patients have the opportunity to comprehensively diagnose cardiac arrhythmias for the disease prevention and continuation of outpatient treatment. Detection of cardiac arrhythmias with automatic notification of medical personnel reduces the response time to a threat to the life and health of the patient. In general, the use of remote cardiac monitoring technologies provides an improved sense of security and contributes to a better effectiveness of treatment.

Conclusion

The prevalence of remote cardiac monitoring devices in Russia largely matches the global trends, although it lags somewhat in its scale. It is important to point out that domestic devices are also present on the market. Comparing the remote cardiac monitoring development in Russia vs. other regions and countries reveals many common trends and problems. On the one hand, the prevalence of such devices in Russia is quite similar to advanced countries. Same is true about Russian devices vs. foreign technological developments and solutions. On the other hand, not all types of devices, depending on their shape and placement methods, are available on the Russian market. At the same time, as in many other countries, the spread of such devices faces technological and sociocultural barriers that can only be solved through the efforts of targeted government policy. New generations of remote monitoring devices are becoming more efficient in terms of their diagnostic power, and the accuracy and reliability of information about the patient's disease. Existing systems allow the collection and analysis of the same information that was previously available exclusively in medical institutions. However, each developer creates an individual closed 'ecosystem'. In this connection, contemporary healthcare requires full integration of existing 'ecosystems' with available electronic medical records, along with spreading this practice to all regions of Russia. However, the *Strategies for the Development of Health Care in the Russian Federation for the Period Up to 2025* do not aim at solving this problem: telemedicine and remote health monitoring procedures are not even mentioned in this document. Currently, the state and relevant specialists in Russia face the important task of understanding the advantages and risks of the widespread use of remote cardiac monitoring devices within the public healthcare system, as well as solving a range of ethical, legal, technological and financial issues related to the creation of a functional and safe digital healthcare system. When integrating

individual services from each manufacturer of cardiac monitoring devices into a single unified healthcare system, one of the promising directions is the use of AI systems for processing the data on health status and promptly informing patients and doctors, thereby contributing to the prevention of cardiovascular diseases.

Conflict of interest

The authors declare that they have no conflict of interest.

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