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# Remote monitoring of chronic noncommunicable diseases: potential in the COVID-19 pandemic

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## ABSTRACT

**Aim.** To review the current progress in the use of remote health monitoring (RHM) technologies for chronic noncommunicable diseases (CNCD).

To search for data, we used Web of Science, Scopus, Russian Science Citation Index, Academic Search Complete (EBSCO), Cochrain, and PubMed databases. The date range was 5–10 years. The importance of development of RHM technologies and their further study was shown to confirm the evidence of effect of certain RHM systems.

New approaches to the integration of the medical community into the international telemedicine strategy are considered. It was established that RHM can potentially decrease treatment costs and reduce the burden on medical organizations. The review analyzes the experience in using RHM in patients with cardiovascular diseases, as well as respiratory and endocrine disorders. The review also summarizes and systematizes the findings of studies on assessing the effectiveness of RHM technologies in clinical practice, including their use in the COVID-19 pandemic.

It is noted that despite high interest of the scientific community in the study of RHM technologies, unambiguous results demonstrating the effectiveness of such developments in clinical practice have not been presented.

**Keywords:** chronic noncommunicable diseases (CNCD), remote health monitoring, telemedicine, bronchial asthma, chronic obstructive pulmonary disease (COPD), implantable cardioverter defibrillator (ICD), implantable loop recorder, implantable pacemakers, diabetes, telemonitoring

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# Удаленный мониторинг хронических неинфекционных заболеваний: потенциал в условиях пандемии COVID-19

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**РЕЗЮМЕ**

**Цель:** анализ актуального опыта использования существующих технологий удаленного мониторинга (УМ) хронических неинфекционных заболеваний (ХНИЗ).

Для поиска были использованы базы данных Web of Science, Scopus и Российского индекса научного цитирования, Academic Search Complete (EBSCO), библиотеки PubMed и Cochrain. Глубина поиска – 5–10 лет. Показана значимость развития технологий УМ и их дальнейшего изучения для подтверждения доказательности конкретных методов УМ.

Рассмотрены новые подходы к интеграции медицинского сообщества в международную повестку телемедицины. Установлено, что использование УМ потенциально способно снизить финансовые затраты на лечение пациентов и уменьшить нагрузку на медицинские организации. Проанализированы результаты применения УМ состояния пациентов с патологией сердечно-сосудистой системы, болезнями дыхательной системы, с заболеваниями эндокринной системы. Обобщены и систематизированы результаты исследований, посвященных оценке эффективности применения конкретных технологий УМ в клинической практике, в том числе в условиях пандемии новой коронавирусной инфекции SARS-CoV-2.

Отмечено, что несмотря на высокую заинтересованность научного сообщества в изучении технологий УМ, однозначных результатов, демонстрирующих эффективность разработок в клинической практике, в настоящее время не представлено.

**Ключевые слова:** ХНИЗ, удаленный мониторинг, УМ, телемедицина, бронхиальная астма, ХОБЛ, имплантируемый кардиовертер-дефибриллятор, ИКД, имплантируемый петлевой регистратор, имплантируемые кардиостимуляторы, сахарный диабет, телемониторинг

**Конфликт интересов.** Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

**Источник финансирования.** Авторы заявляют об отсутствии финансирования при проведении исследования.

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## INTRODUCTION

Current progress in medicine makes it possible to successfully combat many pathological conditions, and synthesis of biomedicine with innovative technologies allows to diagnose many pathologies at early stages. However, despite advances in understanding the etiology and pathogenesis of many diseases, as well as rapid development of pharmacology, mortality from chronic noncommunicable diseases (CNCDs) is currently estimated by the World Health Organization (WHO) at 41 million people, which accounts for 71% of all deaths in the world. Of them, 17 million deaths occur before the age of 70 and are premature [1].

One of the factors contributing to the spread of CNCDs is the problem of their treatment only in the exacerbation phase. Patient parameters are not monitored during remission, and, therefore, a doctor is not able to timely adjust the backbone therapy and treatment strategy. In accordance with the above-mentioned, as well as with the current conditions of a novel coronavirus infection SARS-CoV-2 (COVID-19) pandemic, uncontrollable increase in the disease incidence, and high burden on the healthcare system, innovative digital remote health monitoring (RHM) technologies are gaining momentum. The use of RHM technologies can potentially decrease treatment costs due to remote diagnosis and treatment, as well as reduce the burden on medical organizations and risks of complications from chronic diseases [2–4].

The unprecedented spread rate of COVID-19 requires changes in a usual lifestyle, in particular, reducing to a minimum contacts with people and observing the self-isolation regime [5, 6]. Recommendations on reducing the number of physical contacts between patients and healthcare professionals are defined by the European Center for Disease Prevention and Control (ECDC) and WHO as medical distancing [7, 8]. The need to comply with the ECDC and WHO recommendations increases the importance of new digital technologies and demand of the healthcare system for them.

Nevertheless, a significant barrier to introduction of RHM into medical practice is a small number of randomized clinical trials in this area, as well as a lack of systematic reviews on this topic, which casts doubt on the evidence of effect of RHM methods for controlling CNCDs and the possibility of their use in the post-COVID-19 era [9–11].

The aim of this study was to systematize and review the current progress in the use of RHM technologies and assess their effectiveness for patients in clinical trials, including their use in the COVID-19 pandemic.

## MATERIALS AND METHODS

This review includes randomized clinical trials published from 2010 to 2020. The Web of Science, Scopus, Russian Science Citation Index, Academic Search Complete (EBSCO), Cochrain, and PubMed databases were used for the search. Key words, such as “telemedicine”, “telemonitoring of CNCDs”, “remote health monitoring”, “cost analysis”, “m-health”, and “SABA monitoring”, were used as search markers. A total of 5,556 publications were found, after the initial screening, 864 publications were included in the analysis, of which 86 were included in the comparative analysis. In addition, the review includes earlier studies that make it possible to assess the historical perspective of the effectiveness of RHM technologies for assessing the condition of patients with CNCDs.

## PATIENTS WITH CARDIOVASCULAR DISEASES

In the Russian Federation, according to the statistical report of the WHO (2017), CNCDs account for 86% of all deaths, most of which are related to cardiovascular diseases (60%) [12, 13]. Currently, implantable pacemakers (IPM) and implantable cardioverter defibrillators (ICDs), which correct heart rhythm disorders, as well as implantable loop recorders, which perform remote electrocardiogram (ECG) monitoring, play an essential role in the diagnosis and treatment of chronic cardiovascular diseases.

Despite high diagnostic efficiency of these devices, there is a need for regular visits to a doctor to analyze the operation of a device and assess the clinical condition of a patient. Currently, such visits can be avoided due to IPM and ICD equipped with a RHM system and clinically tested in a number of countries [14].

A group of scientists from the BIOTRONIK global medical device company carried out a multicenter, prospective, randomized trial in 2010 aimed at safely reducing the number of standard checks of office devices. In this study, a group of patients ($n$ = 977) were implanted with an IPM with the RHM function, while another group of patients ($n$ = 473) were implanted with an ICD without RHM. According to the results of the study, 3,099 out of 3,316 possible planned follow-up observations were performed in the first group, compared with 1,354 out of 1,526 observations in the control group (93.5% versus 88.7% within 12 months, $p < 0.001$), which indicates more careful adherence to routine health checks in the group with RHM. It is important to note that the average number of doctor’s visits (planned and unplanned) was 2.1 per patient per year for the RHM group and 3.8 for the control group. Thus, it was shown that RHM reduces the total number of doctor’s visits by 45% and at the same time contributes to more effective detection of asymptomatic abnormalities [15]. Similar results were obtained by Adamson et al. (2012) at the Oklahoma Heart Hospital [16]. Later, Ching et al. (2016) in their experiment proved the effectiveness of RHM in patients with ICD, as well as permanent IPM and implantable defibrillators for cardiac resynchronization therapy [17].

L. Guedon-Moreau et al. in 2013 confirmed and supplemented the data obtained in the study by BIOTRONIK. Participants of the study with ICD equipped with the RHM system ($n$ = 221) were invited for a face-to-face examination only at the 1st, 3rd, and

27th months after ICD implantation. Participants from the control group ($n$ = 212) were additionally invited at the 9th, 15th, and 21st months after ICD implantation. The group of patients whose ICD transmitted data to the doctor reduced the burden on the hospital to 1.46 visits per patient per year, in contrast to the control group with 2.23 visits per patient per year [15, 18].

The group of researchers led by P. Mabo (2010, 2012) also demonstrated a decrease in the number of outpatient observations per patient per year in the group with RHM (0.51 ± 0.71 (95% confidence interval (CI): 0.43–0.59) versus 1.15 ± 1.07 (95% CI: 1.03–1.27)) compared with the control group. Their results also showed high efficiency of RHM in identifying various disturbances in the ICD operation. In the COMPAS (Cardiovascular Outcomes for People Using Anticoagulation Strategies) study ($n$ = 494) conducted by the same group of scientists, it was shown that the use of the RHM system may decrease the interval between the onset of cardiac events and a doctor's examination by 117 days for patients with IPM compared with traditional follow-up ($p < 0.001$ )[19].

H. Versteeg et al. in 2019 conducted one of the first multicenter, randomized trials in parallel groups on the efficiency and safety of ICD, assessing the effect of implantation and RHM on the quality of life (QOL) in patients during 2 years of post-implantation follow-up. Patients with ICD were randomized into two groups. The first group was experimental ($n$ = 300) and included RHM with annual examination and consultation in a medical organization. The second group ($n$ = 295) implied registration of ICD data without RHM in a medical organization for 3–6 months during 2 years after implantation. QOL and well-being were assessed using the Kansas City Cardiomyopathy Questionnaire (KCCQ) and the Florida Patient Acceptance Survey (FPAS). The authors found that the mindset of patients in the first two years of the post-implantation period can completely replace meetings with medical professionals. The results of the study showed an insignificant statistical difference in the QOL and well-being of patients after ICD implantation in different post-implantation periods (3.3 points on both scales, (beta –6.41; 95% CI: $p$ = 0.001) [20].

G.H. Crossley et al. (2011) demonstrated that clinical decision-making in patients with RHM is reduced on average by 17.4 days and amounts to 4.6 days ($p < 0.001$), whereas standard follow-up observations allow to make decisions on average only 22 days ($p <0.001$) after the emergence of disorders in the cardiovascular system [21].

In addition to IPM and ICD, there are systems that allow for remote monitoring of systolic blood pressure parameters in patients with cardiovascular diseases. For example, Abbott Corporation (Abbott, Illinois, USA) launched a CardioMEMS Heart Failure Sensor (CardioMEMS HF Sensor) on the US market in 2014. CardioMEMS HF Sensor is a diagnostic system for monitoring heart failure which is implanted into the pulmonary artery (PA) and monitors systolic blood pressure, accumulating data on the functions of the cardiovascular system on the server [22].

P.B. Adamson et al. (2011) implanted this sensor in 550 patients with NYHA (New York Heart Association Functional Classification) functional class III chronic heart failure (CHF). The results showed that if the doctor was granted access to PA pressure readings remotely, the hospitalization rate decreased by 33% compared with the control follow-up. The authors also pointed out that the decrease in the hospitalization rate was associated with a possibility of taking preventive measures to eliminate the attack based on daily RHM [23, 24]. After the sensor was introduced in the market, the same team of researchers determined the effectiveness of the device based on data from 2,000 patients [25]. Later in 2018, a retrospective study was conducted in Los Angeles confirming the decrease in the number of hospitalizations ($n$ = 73) and improvement in hemodynamic parameters in patients with an implantable CardioMEMS HF Sensor [26].

A number of studies prove the effectiveness of RHM in patients with essential hypertension. For example, B. McKinstry et al. compared standard blood pressure control in the medical organization and control using RHM (2013). After a six-month follow-up, the difference in systolic and diastolic blood pressure in the control group ($n$ = 201) and the RHM group was 4.3 mmHg (95% CI: 2.0–6.5; $p$ = 0.0002) and 2.3 mmHg (95% CI: $p$ = 0.001), respectively. In a retrospective comparison, it was found that 39% of participants in the RHM group promptly increased the daily dose of the antihypertensive drugs, while in the control group, the proportion of such participants was only 12% ($p$ = 0.0003) [27].

J. Evans et al. (2016) showed that the use of a wireless, wristwatch-based monitoring device that continuously recorded health data in patients over 55 years with the underlying cardiovascular disease reduced hospitalizations to a heart hospital [28, 29].

The effectiveness of RHM in terms of blood pressure control has also been demonstrated by K.L.Margolis et al. (2013). In their study, after a six-month follow-up in the control group ($n$ = 222), the target blood pressure level was achieved in 30% of patients (95% CI: 23.2–37.8); in the RHM group, the target value was achieved in 57.2% of participants (95% CI: 44.8–68.7). The difference in systolic and diastolic blood pressure between the groups was 10.7 mmHg (95% CI: 14.3–7.7; $p < 0.0001$) and 6.0 mmHg (95% CI: 8.6–13.4; $p < 0.0001$), respectively [30].

E. Piotrowicz et al. (2019) conducted a large, multicenter, prospective, open-label, randomized clinical trial to evaluate the implementation of hybrid comprehensive telerehabilitation (HCTR) in clinical practice. The study involved 850 patients with CHF 6 months after hospitalization with NYHA functional class I, II, and III CHF and left ventricular ejection fraction (LVEF) of 40% or less according to the Simpson's ejection fraction tool. For 9 weeks, the patients underwent a telerehabilitation program (1 week in the medical organization and 8 weeks outside the medical facility), which included RHM, taking medications, and undergoing rehabilitation in the medical organization.

After 26-month follow-up, the average duration of hospital stay in the RHM group ($n$ = 425, 91.3 days) showed a statistically insignificant difference compared with the control group without the implementation of the telerehabilitation program ($n$ = 425, 92.8 days) (95% CI: 0.46–0.53; $p$ = 0.74). During the follow-up, the number of deaths after 24 months of the program implementation in the RHM group was 54 (12.5%) versus 52 (12.4%) in the control group (95% CI: 0.70–1.51). There was also no statistically significant difference in the hospitalization rate (95% CI: 0.79–1.13). During the study, cardiorespiratory endurance test parameters for determining peak oxygen consumption were 0.00 ml / kg / min (95% CI: 0.31–0.30; $p < 0.001$) versus 0.95 ml / kg / min (95% CI: 0.65–1.26; $p < 0.001$) in the control group and the RHM group, respectively. The QOL in the patients had been assessed using a non-specific questionnaire for assessing the quality of life (SF-36, The Short Form-36) over 24 months: 1.58 (95% CI: 0.74–2.42, $p$ = 0.008) versus 0 (CI 95%: -0.84–0.84, $p$ = 0.008) in the experimental and control groups, respectively. Therefore, the implementation of RHM into clinical practice did not contribute to a decrease in the number of days spent in the medical institution per patient and the number of hospitalizations and deaths [31, 32].

Insignificant differences in the hospitalization rate between the control ($n$ = 110) and experimental ($n$ = 223) groups were noted (34.5% versus 39.1%, $p$ = 0.48), however, significant improvement in QOL according to SF-36 in the experimental group (2.6 points for physical wellbeing, $p < 0.0001$; 1.69 points for mental health, $p$ = 0.4) was demonstrated in the study by Olivari et al. (2018) [33].

J.P. Halcox et al. (2017) conducted a randomized, controlled trial (RCT) on the risk of atrial fibrillation (AF) in 1,001 patients over 65 years of age using a Wi-Fi AliveCor heart monitor with the function of connecting to a mobile device. All studied patients were divided into a control group ($n$ = 501) and an experimental group ($n$ = 500) depending on the parameters of the risk assessment scale for thromboembolic complications in patients with AF. During the first 12 months, AF was diagnosed in 3.8% of patients in the experimental group compared with 1% of patients in the control group (risk ratio (RR) = 3.9; 95% CI: 1.4–10.4, $p$ = 0.007). The proportion of patients with thromboembolic complications (acute cerebral stroke, transient ischemic attack, systemic thromboembolism) in the experimental group was 1.2% versus 2% in the control group (RR = 0.61; 95% CI: 0.22–1.69, $p$ = 0.34 ), which confirms the role of RHM in prevention and early diagnosis of complications of cardiovascular diseases [34].

Similar results were obtained by M.J.Reed et al. (2018); they proved the effectiveness of remote monitoring of the risks for AF in emergency care units with the ability to synchronize AliveCor with mobile devices of medical personnel [35]. However, there are studies that have proven the absence of a relationship between a positive outcome of patient treatment and RHM. Thus, the results obtained by J.H.Morgan et al. (2017) in the clinical study of RHM in patients with CHF using an ICD did not confirm the role of RHM in reducing the number of hospitalizations [36–39].

A.P.Vanezis et al. (2018) evaluated the efficiency of remote ischemic preconditioning (RIPC) for restoration of reduced (less than 45%) LVEF in patients after ST-segment elevation myocardial infarction ($n$ = 73) who underwent percutaneous coronary intervention (PCI). The baseline mean value for LVEF in the experimental and control groups ($n$ = 38) was comparable both before and after 4 weeks of the follow-up ($p$ = 0.952) [40].

Implantable antiarrhythmic devices (IADs) which are therapeutic and diagnostic systems that collect and transmit statistical information about the health status of a patient with heart rhythm disturbances play a crucial role in RHM of patients with cardiovascular diseases [41]. According to a number of domestic researchers, the number of IADs is growing rapidly; currently, about 300 devices are implanted per one million population in the Russian Federation. A review presented by a group of authors led by N.N. Lomidze et al. (2019) reported data on the RHM system "Home Monitoring" manufactured by Biotronik, which is based on RHM of patients with IAD via a mobile phone. The data received from the device are transmitted to a unified service portal with subsequent analysis of the information, which is then remotely transmitted to the attending physician.

A group of researchers from the Vishnevsky National Medical Research Center of Surgery (Moscow) demonstrated the effectiveness of using ICDs ($n = 56$) and pacemakers ($n = 7$) manufactured by Biotronik. The average age of the patients was 57.0 ± 11.6 years. Most of the subjects ($n = 45$) were implanted with ICDs due to the presence of paroxysmal ventricular tachycardia (PVT) or ventricular fibrillation (VF), the rest ($n = 11$) were implanted with ICDs to prevent sudden cardiac death. Every day, the received data were transmitted to the doctor via the Biotronik "Home Monitoring" system. On average, the follow-up period was 24.5 ± 17.4 months, and the number of critical situations per 1 patient per year according to RHM data was 35.3 ± 33.6 [41].

The research on the attitude of patients to RHM is particularly worth mentioning. I.Timmermans et al. (2018) analyzed patient satisfaction ($n = 300$) with RHM, as well as their preferences. It was found that 12 months after the implantation, the average patient satisfaction with RHM was 0.8 (interquartile range = 7–10). Of 244 patients, 44% preferred RHM, 16% preferred face-to-face follow-up in the medical organization without RHM, and 40% of patients did not express any preference. In addition, it was found that patients without RHM were much more likely to receive resynchronization therapy ($p = 0.018$), which confirms the preventive role of RHM. It is worth noting that RHM patients were more likely to report well-being during the study ($p = 0.02$ and $p = 0.017$) and were satisfied with the ICD performance [42].

Summarizing the results of the studies on RHM methods in cardiac patients, it can be concluded that currently the use of RHM technologies can improve the patient's condition, but does not always help to reduce mortality, hospitalization rate, and risks of disease exacerbation.

## PATIENTS WITH RESPIRATORY DISEASES

According to the WHO estimates, 65 million people worldwide suffer from moderate to severe chronic obstructive pulmonary disease (COPD), and 235 million people suffer from bronchial asthma (BA). Nearly 90% of COPD deaths occur in low- and middle-income countries. In addition, in 2017, more than 120,000 patients with BA, more than 380,000 patients with chronic and unspecified bronchitis, and 95,000 patients with COPD were registered in the Russian Federation [43].

In the study by P.H. Lilholt et al. (2017), during 12-month follow-up, patients from the group with the ability to remotely measure blood pressure, oxygen saturation level, and heart rate ($n = 258$) were required to regularly fill out the SF-36 questionnaire. Study participants without RHM were included in the control group ($n = 316$). According to the results of the analysis, the difference between the SF-36 scores in the RHM group and the control group was statistically insignificant and amounted to 0.2 points (95% CI: 0.9–1.3) and 0.4 points (95% CI: 1.0–1.7), respectively [44].

Similar results were demonstrated by P.P. Walker et al. (2018) using the European Quality of Life Questionnaire (EuroQoL EQ-5D). In addition, the difference in the number of exacerbations of COPD in the control and experimental groups (1.74 versus 1.52; $p = 0.499$), the number of hospitalizations (0.79 versus 0.99, $p = 0.276$), and the number of patients not hospitalized during the study (71% versus 74%, $p = 0.599$) were statistically insignificant. Nevertheless, the followed-up patients previously hospitalized with the exacerbation of COPD showed a 53% decrease in the hospitalization rate ($p = 0.017$) compared with the control group [45]. A number of studies with a similar design also demonstrated that there is no significant difference in the clinical presentation between the standard care COPD group and the RHM COPD group, and the number of hospitalizations and exacerbations also changes insignificantly [46–48].

A. Farmer et al. (2017) conducted six-month monitoring of patients with COPD, which revealed that in the control group ($n = 166$) and the group with RHM ($n = 110$), the differences in the clinical presentation according to the scores of the St.George's Respiratory Questionnaire for patients with COPD (SGRQ-C) were insignificant ($p = 0.69$ and $p = 0.49$). However, the use of RHM contributed to a decrease in the number of physical examinations by a doctor in the RHM group compared to the control group (4 versus 5.5; $p = 0.06$), as well as in the number of hospitalizations [RR = 0.83; 95% CI: 0.56–1.24, $p = 0.37$] [49].

A slight difference in the parameters between the control and RHM groups in the studies described above may be due to a high level of medical care for patients with COPD in the countries where the studies were conducted, which may reduce the positive effect of RHM technologies. It should be noted that modern equipment for remote measurement of spirometry parameters requires further study and improvement, which is confirmed in the paper by V.I.Sirichana et al. (2014) [50].

Data from a number of studies prove that RHM systems in BA are potentially capable of improving symptom control and tracking patient's medication intake [51]. M.A.Barrett et al. (2017) demonstrated the effect of RHM of the use of β-adrenergic agonists on BA control. The authors used an inhaler with a sensor that remotely monitored the frequency of inhalations, as well as spotted the location of the patient. The study included 95 participants who used the sensor for at least 60 days, 30 of which were the control period, the data on the frequency of inhalations were not transmitted to the doctors and participants themselves. According to the results of the study, the number of inhalations per patient was 0.27 per day, which is 39% (0.44) smaller than in the control period. For the participants who completed the study within 12 months ($n$ = 35), the proportion of asymptomatic days was 95%, which is 23% more than the baseline value. Throughout the follow-up, asthma control significantly improved, which was associated with regular assessments and discussions of certain attacks that provoked the need for inhalations with the doctor [52].

R.C.Merchant et al. (2016) obtained similar results on RHM of the use of inhaled drugs. After 12 months of monitoring in the control group ($n$ = 247), the average number of seizures decreased by 0.31 versus 0.41 ($p < 0.001$) in the RHM group, and the number of days without seizures increased by 17% versus 21% ($p$ = 0.01), respectively [53]. Kew et al. (2016), however, demonstrated an insignificant difference between face-to-face and remote forms of BA control in terms of the frequency of exacerbations, BA control, and the quality of life in patients [54].

In the study by J.C. de Jongste et al. (2009), children with BA were randomly divided into two groups: in the first group, the participants used a device for monitoring airway inflammation, which recorded the amount of nitric oxide during exhalation; the second group was the control group. In addition, each participant in both groups recorded their asthma attacks in an electronic diary. As a result of the three-month study, a decrease in the dose of the inhaled corticosteroid (400 mg versus 200 mg; $p < 0.0001$) and an increase in the number of asymptomatic days in both groups were noted. In addition, the forced expiratory volume improved from 88% (AV (average volume) of 13% for group 1; AV of 15% for group 2) to 95% (AV of 14% for groups 1 and 2). There was no significant difference between the groups. The authors of the study concluded that only the electronic diary contributed to such improvements, while monitoring of inflammatory markers did not affect the improvement of the patients' condition [55].

## PATIENTS WITH ENDOCRINE DISEASES

Another important group of CNCDs includes pathologies of the endocrine system. Currently, according to the International Diabetes Federation, over 425 million people suffer from diabetes mellitus (DM) worldwide [56]. Taking into account the peculiarities of the course and complications of this disease, RHM of patients can be of great importance in the work of an endocrinologist [57].

M.L. Michaud et al. (2018) compared standard control of health parameters in patients with type 2 diabetes (T2D) in the medical organization and control with the use of RHM. Study participants ($n$ = 955) for three months measured blood pressure, blood glucose level, and body weight daily with the ability to upload data to a unified server. In addition, they contacted healthcare professionals on a weekly basis for dietary adjustments, self-management counseling, and compliance assessments. Prior to study initiation, the mean glycosylated hemoglobin ($HbA_{1c}$) value in the participants was 7.92%, and after the end of the study, it was 7.09% ($p < 0.001$). Besides, the number of participants with $HbA_{1c} > 9\%$ decreased from 213 to 93 ($p < 0.001$) [58].

The effectiveness of RHM in terms of controlling $HbA_{1c}$ levels has been demonstrated by A. Steventon et al. (2014). In their study, after 12-month follow-up in the RHM group ($n$ = 300), the $HbA_{1c}$ level decreased by 0.21% (2.3 mmol / l) versus 0.1% in the control group (95% CI: 0.04–0.38; $p$ = 0.013). The design of the project involved the use of a glucometer with a RHM function by patients from the RHM group, as well as completion of an online questionnaire about their wellbeing [59].

Similar results were obtained in the study by S.H. Wild et al. (2016), where in the RHM group ($n$ = 146), the $HbA_{1c}$ level decreased by 5.6 mmol / l (95% CI: 2.38–8.81, $p$ = 0.0007) and reached 57. 4 mmol / l.

In the control group ($n$ = 139), the $HbA_{1c}$ level was 67.8 mmol / l. The analysis of the results also showed a decrease in systolic blood pressure by 3.06 mmHg (95% CI: 0.56–5.56 mmHg; $p$ = 0.017) and diastolic blood pressure by 2.17 mmHg (95% CI: 0.62–3.72 mmHg; $p$ = 0.006) in the RHM group [60].

The effectiveness and safety of RHM in patients with T2D was studied by J.Y. Jeong et al. (2018). Study participants were divided into a control group without RHM ($n$ = 113) and two groups with RHM, which received follow-up for 24 weeks. In the groups with RHM, a glucometer and a bioimpedance body composition analyzer with the function of remote data processing were used. According to the results of the study, all three groups showed a decrease in the level of $HbA_{1c}$ (-0.66% ± 1.03% in the control group, –0.66% ± 1.09% in the group with RHM and –0.81% ± ± 1.05% in the group with remote consultations, $p$ < 0.001), whereas in the groups with RHM the decrease in the $HbA_{1c}$ level was statistically insignificant [61].

Similar results were obtained in the study by C. Dario et al. (2017), where after 12-month follow-up, the difference in the $HbA_{1c}$ level between the RHM group and the control group was 0.01 (-0.26 ± 0.92 versus -0.27 ± 0.99, respectively, $p$ = 0.76). The authors also noted that RHM made it possible to reduce the number of doctor's visits of the participants ($p$ < 0.0001) and the number of hospitalizations ($p$ = 0.02) [62].

Summarizing the results of the presented studies, it can be stated that today the advantage of using RHM for controlling and diagnosing the health status of patients with T2D is not obvious and requires further study.

## DISCUSSION

Therefore, despite high interest of the scientific community in the study of RHM technologies, there are currently no unambiguous results demonstrating the effectiveness of RHM systems in clinical practice.

Positive results on the use of RHM were demonstrated by the authors who studied the advantages of RHM in diseases of the cardiovascular system, which can have direct practical application in cardiology centers and at local visits to a cardiologist. These studies show significant improvements in patients' health status and a decrease in the number of hospitalizations. In addition, RHM of the condition of a patient with cardiovascular diseases makes it possible to create unified databases with the results of monitoring patients with ICD and IPM, which will contribute to accumulation of medical data and maintenance of personal electronic health records [63]including resource management, medical process management and care delivery. A great number of the Internet users in Russia has a significant impact on integration of Internet technologies into all areas of public life, including health care. Purpose is to identify most perspective directions for development of Internet technologies in (domestic.

It should be noted that the effectiveness of RHM implementation in patients with cardiovascular diseases requires further study and systematization of methods for processing data obtained using the RHM systems. The latter is supported by a number of studies, including the work by G. Pounds et al. (2017), devoted to the analysis of the efficiency and labor costs of medical personnel in evaluating data obtained from implantable loop recorders, as well as the results of a randomized, prospective, multicenter, economic trial within the EuroEco project in the work by H. Heidbuchel et al. (2015) [64, 65].

Some researchers in the field of endocrinology agree that glucometers with the ability to remotely transmit physiological data are not significantly more effective than standard devices, where patients are forced to independently control their blood glucose level [61, 62]. Similar ambiguity is also observed in the works by authors who studied the effectiveness of RHM in COPD [46–48]. According to a number of described studies, the introduction of RHM technologies in work with BA patients can lead to positive results [52, 53]. Remote monitoring of the number of inhalations and maintenance of an electronic patient diary improve disease control and reduce the number of seizures [55].

At the same time, in such studies, factors indicating the unsafe use of RHM technologies are overlooked. In addition, the authors of most of the works report a decrease in the number of face-to-face meetings with doctors when using RHM, which in the long term results in a decrease in the burden on medical institutions. It is worth noting that the ambiguity of the impact of RHM technologies can also be determined by the level of classical medical care for patients with chronic diseases in a particular country, and high quality of standard follow-up can reduce the positive impact of RHM on patient's health.

It is especially important to assess the potential of applying RHM in the context of the COVID-19 pandemic and the possibility of using RHM technologies in the post-COVID-19 era. Isolated studies on the use of specific RHM technologies for patients with COVID-19 and a lack of systematic reviews on the use of RHM in a pandemic cast doubt on the evidence of effect of RHM methods and require further study [9, 10, 66–69].

Special attention should be paid to the economic component of the effectiveness of RHM implementation in practical medicine. It is noted that most of the scientific publications on RHM are considered as a promising area of preventive medicine that helps to overcome the costs of the healthcare system, reduce the burden on the budget, and accelerate adaptation of healthcare to modern conditions of a market economy. There is a number of studies confirming the economic feasibility of introducing RHM into practical medicine [70, 71]. J. P. Hummel et al. (2019) conducted a large study (n = 15,254) analyzing the economic model for RHM implementation in patients with ICD. The data obtained indicated a decrease in the readmission rate and, as a consequence, a decrease in costs by 554 USD per patient per year in the RHM group ($n$ = 5,348). It is worth noting that the total costs of visits to doctors and outpatient services were higher in the RHM group (47,515 versus 42,792 USD), but the average cost per patient per year was lower (6,232 versus 6,244 USD), which confirms high economic feasibility of introducing RHM into clinical practice [72].

A similar study by A. Capucci et al. (2017) demonstrated an assessment of economic benefits from the introduction of RHM in patients with ICD after acute coronary syndrome. As a result of 12-month follow-up of patients in the RHM group ($n$ = 457) compared with the control group ($n$ = 401), the readmission rate was 0.16 / year versus 0.27 / year (RR = 0.59, $p$ = 0.0004). At the same time, the annual cost of treatment per patient was 817 euros in the control group versus 604 euros in the RHM group ($p$ = 0.0004) [70].

Despite the differences in the obtained results and polarity of the conclusions, the study of the effectiveness of RHM implementation into clinical practice continues, and protocols of new studies are being published in international journals [31, 73, 74]. The COVID-19 pandemic, as well as a number of economic, geographic, and social factors dictate the need for the medical community to actively integrate into the international telemedicine strategy and develop RHM technologies in the Russian Federation.

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