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Shevtsov Ivan, Postgraduate student
https://orcid.org/0000-0003-0597-1589
Kharkiv National University of Radio Electronics, Kharkiv, Ukraine

ACTUAL PROBLEMS OF REMOTE PATIENT MONITORING

Shevtsov I. Actual problems of remote patient monitoring. Remote patient monitoring (RPM) is an innovative technology that provides continuous monitoring of patients' health from a distance. The RPM system is versatile because it can be used in the treatment of acute and chronic conditions, helping doctors keep their patients under control between ward rounds or the absence of personal care. However, the implementation of this system is accompanied by numerous problems: from technical to hospital staff management problems. The object of this study is the technical challenges associated with the use of the RPM system. The problem lies in the imperfection of many elements of RPM, including: data management, sensor accuracy, compatibility and user acceptance of the technology. The research found that these technical challenges arise from insufficient standardization, poor sensor data quality, and interoperability issues between medical platforms. These results are explained by the complexity of the technological infrastructure and the need to improve the qualifications of medical workers. The main goal of the current article is to solve the scientific and technical problem of RPM through the proposal of an effective practical development - an automated system for remote monitoring of patients. Since most processes are moving towards their automation, by using the latest scientific developments, among which we can recall machine learning and neural networks and Internet of Things (IoT) technology, it was decided to consider the factors of their application in remote patient monitoring systems. The results of this study can be used to optimize RPM systems in hospitals, as well as to improve the reliability and efficiency of new automated monitoring systems, which is extremely important in the context of war, which causes a shortage of medical personnel and an increase in the number of potential patients per doctor.
Keywords: remote patient monitoring, data management, interoperability, sensor accuracy, technology adoption, automation, algorithms.

Шевцов І.О. Актуальні проблеми дистанційного моніторингу пацієнтів. Дистанційний моніторинг пацієнтів (ДМП) – це інноваційна технологія, яка забезпечує безперервний нагляд за станом здоров'я пацієнтів на відстані. Система ДМП є універсальною, оскільки її можна використовувати при лікуванні гострих та хронічних станів, що допомагає медикам тримати їх пацієнтів під контролем між обходами палат або відсутністю особистого догляду. Однак впровадження цієї системи супроводжується численними проблемами: від технічних до проблем менеджменту персоналу лікарень. Об'єктом цього дослідження є технічні виклики, які пов'язані з використанням системи ДМП. Проблема полягає у недосконалості багатьох елементів ДПМ, серед яких: управління даними, точність сенсорів, сумісність та сприйняття технології користувачами. У результаті дослідження було виявлено, що ці технічні виклики виникають через недостатню стандартизацію, низьку якість сенсорних даних та проблеми з інтероперабельністю між медичними платформами. Ці результати пояснюються складністю технологічної інфраструктури та потребою в підвищенні кваліфікації медичних працівників. Головною метою поточної статі є вирішення науково-технічної проблеми ДПМ через пропозицію ефективної практичної розробки – автоматизованої системи дистанційного моніторингу пацієнтів. Оскільки більшість процесів рухається до їх автоматизації, шляхом використання новітніх наукових розробок, серед яких можна пригадати машинне навчання та нейромережі і технологію Інтернету речей (IoT), то вирішено було розглянути фактори їх застосування і в системах дистанційного моніторингу пацієнтів. Результати цього дослідження можуть бути використані для оптимізації систем ДМП у лікарнях, а також для підвищення надійності й ефективності нових автоматизованих моніторингових систем, що є надзвичайно важливим в умовах війни, що викликає дефіцит медичних працівників та збільшення потенційних пацієнтів з розрахунку на кожного лікаря.
Ключові слова*:* дистанційний моніторинг пацієнтів, управління даними, інтероперабельність, точність сенсорів, прийняття технологій, автоматизація, алгоритми.

Formulation of the problem.

The rapid evolution of healthcare technology has made remote patient monitoring (RPM) an increasingly crucial element of modern healthcare systems. The ability to monitor patients' health remotely, particularly those with chronic conditions or who require consistent medical supervision, has revolutionized care delivery by reducing hospital visits and enabling continuous health assessment [1]. Provider associations and patient associations claim that RPM systems are effective in improving or maintaining quality of care, further encouraging its use and adoption [2]. However, despite the significant advantages of RPM, it also presents several technical challenges that hinder its widespread adoption and optimal use. Research into the technical challenges of remote patient monitoring has become more critical than ever.

The global rise in chronic diseases, aging populations, and the current burden on healthcare systems necessitate efficient and reliable RPM systems. By addressing and overcoming the technical hurdles, researchers and engineers can improve the quality of patient care and enhance healthcare outcomes [3].

The relevance of studying these challenges is grounded in the increasing reliance on RPM systems, especially in the post-pandemic era [4]. Real-time data transmission, sensor technology, and data security are just a few areas that demand innovation to meet growing healthcare needs. Some groups of technicians

working at hospitals have already developed their programs for remote monitoring of patients discharged from the hospital after treatment for COVID-19, but they are able to perform a narrow profile of work [5].

The solutions developed from this research will not only reduce the risk of hospitalization but also improve patient management by providing accurate and timely health data for clinicians. Thus, research focused on identifying and resolving technical issues in RPM is highly relevant. Understanding and addressing these issues can facilitate the wider adoption of RPM systems and significantly improve the quality of patient care in a variety of healthcare settings through the automation of these systems.

An analysis of the latest research and publications.

The increasing integration of remote patient monitoring (RPM) technologies into modern healthcare systems highlights both the potential and the challenges associated with real-time data collection and patient management. The following section provides a critical analysis of recent literature on the technical aspects of RPM systems, identifying unresolved problems and offering insights into the reasons for these gaps.

A review of the existing research, particularly in the realm of real-time remote health monitoring systems, underscores significant challenges related to the technical capabilities of sensor technologies and their deployment in priority-based health systems. Albahri et al. emphasize that while real-time RPM can enhance triage efficiency and patient prioritization, significant limitations exist in sensor accuracy, reliability, and interoperability with healthcare infrastructures [6]. The research also highlights the need for more robust algorithms to process the vast amounts of data generated by RPM systems, particularly in critical care settings [7].

Further analysis of the literature reveals that the management and quality of patient-generated health data (PGHD) remain a major issue in RPM. Abdolkhani et al. identify challenges with the integration and standardization of PGHD, which often varies in format and quality, leading to inconsistencies in patient monitoring outcomes [8]. The authors argue that current systems lack the sophistication needed to ensure accurate, timely, and clinically useful data transmission, creating a gap between RPM's potential and its practical application. Moreover, the lack of standardized data protocols contributes to data fragmentation and hampers effective decision-making.

The problem of healthcare practitioner perceptions further complicates the implementation of RPM technologies. Serrano et al. discuss the benefits and challenges as perceived by healthcare professionals, noting that while RPM has been lauded for its potential to reduce hospital readmissions and improve chronic disease management, the perceived technical difficulties often outweigh these benefits [9].

Another important scientific work is the study of Taylor et al. which shows that RPM can reduce acute care use for patients with cardiovascular disease and COPD [10].

Among Ukrainian researchers on the issue of the application of various methods and algorithms for automated monitoring of patients, Boloban and Petrenko should be mentioned and their work studying the features of the application of the EMD algorithm for assessing the level of oxygen in the blood [11].

Uninets I. indicated remote monitoring of patients as one of the components of Smart Healthcare, which has the highest rates of development in the Smart Citizen Services segment [12].

Issues such as inadequate user interfaces, technical malfunctions, and connectivity problems are consistently cited as barriers to broader adoption of RPM technologies. These technical shortcomings are further exacerbated by the lack of training and support for healthcare providers, which limits the effectiveness of RPM in clinical practice.

A systematic review of these studies reveals a common theme: the unresolved issues in RPM primarily stem from technical inadequacies in data collection, integration, and system reliability. Many studies have addressed the need for advancements in sensor technologies and data processing algorithms; however, progress has been slow, primarily due to the complex and multifaceted nature of the problems involved. These challenges are exacerbated by healthcare systems' varying levels of digital readiness and the slow pace of technological standardization.

In conclusion, the literature points to several unresolved problems in the field of RPM. These include sensor accuracy, data standardization, integration challenges, and technical support for healthcare providers. All these problems come down to the main scientific and technical problem of automating patient monitoring, the problem of automating the work of PRM systems. The reasons for these unresolved issues range from technological limitations to systemic barriers within healthcare systems. As such, the next phase of research should focus on addressing these technical shortcomings, particularly in the areas of data standardization, system reliability, and training for healthcare providers, in order to fully harness the

potential of RPM technologies [13]. It is also necessary to consider the experience of automation of PRM systems for a better understanding of this process and algorithms for its implementation.

Formulation of the purpose and objectives of the research.

The aim of this research is twofold, comprising both scientific and practical components.

The scientific goal of the study focuses on identifying the most significant technical challenges in remote patient monitoring systems, as highlighted in recent literature. This involves analyzing the critical gaps in sensor technology, data management, and system integration that remain unresolved despite recent advancements. By investigating these gaps, the research aims to propose improved methods for enhancing the reliability, efficiency, and accuracy of patient monitoring systems, which will ultimately allow the automation of the remote patient monitoring process.

The practical goal is to provide recommendations for the deployment and use of automated remote patient monitoring systems that optimize healthcare delivery, particularly in resource-limited settings. This includes improving the integration of patient-generated data into clinical workflows while minimizing data loss and inaccuracies. Additionally, the research seeks to suggest best practices for maintaining system functionality over long-term usage, addressing both technical and operational limitations.

To achieve these goals, the following research objectives were set:

- Objective 1: To critically analyze and systematize the existing literature on remote patient monitoring systems, focusing on the technical challenges related to sensor accuracy, data transmission, and real-time monitoring capabilities.
- Objective 2: To identify the key factors that contribute to data management challenges in remote patient monitoring, particularly in handling patient-generated data and ensuring its quality and security.
- Objective 3: To evaluate the current technological solutions for overcoming the identified challenges and propose potential improvements in sensor technology, system architecture, and data integration processes [14].
- Objective 4: To assess the practical applications of remote patient monitoring in healthcare settings, identifying limitations in deployment and offering strategies for optimizing the long-term use of these systems.

Through addressing these objectives, this study aims to contribute to the development of more effective and reliable remote patient monitoring systems that can be utilized in diverse healthcare environments, within the Ukrainian legal practice.

Presentation of the main material and substantiation of the obtained research results.

Remote patient monitoring (RPM) has emerged as a significant innovation in healthcare, offering real-time health data and allowing continuous patient oversight. However, despite its promise, RPM faces several technical challenges that hinder its broad implementation and effectiveness. Among these problems is the problem of data management, sensor technologies, compatibility and user acceptance [15].

Remote patient monitoring is an integral part of any modern patient care system. The entire care system is shown in fig. 1.

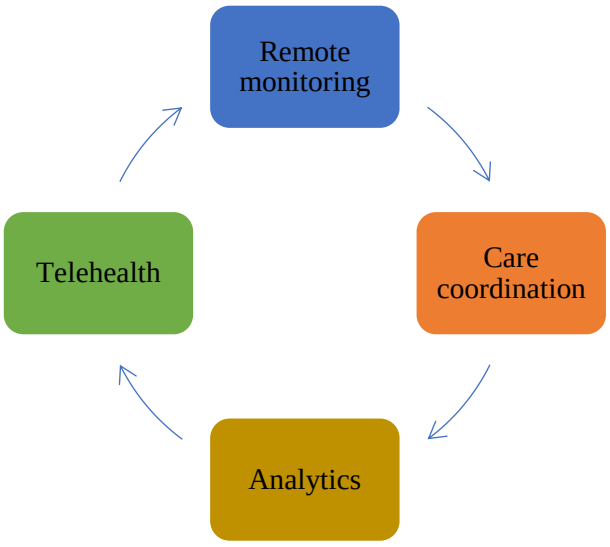

Fig. 1. Modern system of care and diagnosis of patients

Since domestic legislation in the field of health care is rather confusing and ambiguous, remote monitoring of health status, provision of universal access to electronic medical records of patients, conducting medical research using electronic health records of patients require a flexible approach to legal regulation relations in the field of medical data and updating a number of laws [16].

One of the major technical challenges in RPM is the effective management and integration of patient-generated health data. Handling massive amounts of patient-generated data creates significant challenges related to data quality, interoperability, and privacy. For example, fragmented data from multiple devices and platforms makes it difficult to integrate into clinical systems, resulting in delayed response times and reduced decision-making accuracy. In addition, maintaining data privacy while providing real-time access to healthcare providers is another ongoing challenge in RPM systems.

Focusing on the technological challenges in implementing sensor technology in RPM systems, various open challenges related to the deployment of real-time remote health monitoring systems need to be identified, particularly with respect to sensor accuracy, reliability, and energy efficiency [17]. Many current sensors struggle to maintain stable performance in various environmental conditions, leading to inaccuracies in patient data. In addition, energy consumption in continuous monitoring systems remains a critical issue, as battery limitations often prevent continuous long-term monitoring [8].

Another major problem in RPM is the lack of standardized protocols and system compatibility. The lack of uniform standards for device communication prevents the seamless exchange of data between different healthcare systems. Interoperability issues not only limit the integration of RPM data into electronic health records, but also make it difficult to scale RPM solutions across healthcare providers and institutions. The development of common standards and communication protocols is important for solving this problem [9].

A less technical, but no less important, issue is the user acceptance of RPM systems by both patients and healthcare professionals. The success of RPM systems is largely dependent on patients' ability to properly use the monitoring devices and software. However, insufficient training and support may result in incorrect data collection or device malfunction. Healthcare providers also face challenges in adapting to new technologies, especially in environments with limited IT infrastructure or technical support. Addressing these training needs is critical to ensuring the successful implementation of RPM [14].

Turning to the question of automation of remote monitoring systems, it should be mentioned that among the devices included in such a system there should be only those that show the main indicators of the body, since a large number of devices can overload the system, and this, in turn, will cause delays and obtaining inaccurate results. Devices that are usually included in the system of remote monitoring of the patient are shown in fig. 2.

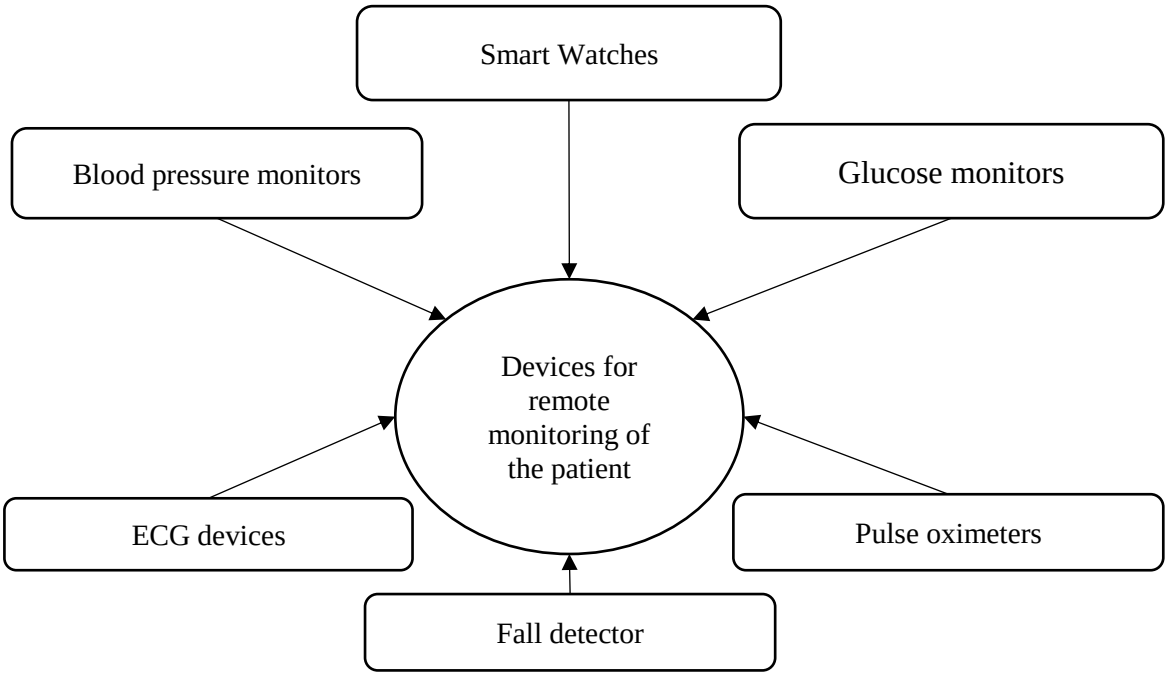

Fig. 2. Main devices used in automated RPM systems

Below is a description of the value of devices for detecting key indicators in the patient being monitored:

1. Blood pressure monitors: a person can use an IoT blood pressure monitor to record their blood pressure in the app and view any patterns using the generated graphs. If necessary, the doctor can receive blood pressure results by e-mail and provide accurate information about treatment. In terms of connectivity, Bluetooth and Wi-Fi are mainly used by IoT blood pressure devices.
2. Glucose monitors: self-monitoring of blood glucose (SMBG) helps to plan intensive diabetes treatment. White-coat hypertension, which affects those adversely affected by the hospital environment, can be prevented through self-management.
3. ECG devices: The electrical activity of the heart can be measured and recorded using ECG (electrocardiogram) equipment. Electrodes, which are tiny sticky pads, are stuck to the skin of the patient's arms, legs and chest to work with the machine. The electrodes transmit the electrical signals they receive from the heart to the ECG equipment.
4. Pulse oximeters: pulse oximeters are devices that measure the amount of oxygen in a person's blood. The use of pulse oximetry screening as a method for detecting serious congenital heart defects is one of the most remarkable advances in the market for pulse oximetry (CCHDs).
5. Fall detector: can provide a warning signal in the event of a fall. Elderly people, cyclists and hikers who use a fall detector can use it to sound an alarm and seek help.
6. Smart Watches: tracks daily activities such as steps, calorie consumption, heart rate, blood oxygen level, blood pressure and body temperature [18].

These devices are especially useful when working with vulnerable categories of the population (elderly people and persons with disabilities).

Most modern remote patient monitoring systems use artificial intelligence technologies and algorithms. The integration of artificial intelligence (AI) into remote patient monitoring (RPM) has revolutionized healthcare, improving patient care, increasing efficiency and enabling early intervention. The introduction of artificial intelligence algorithms increases the potential of RPM systems by analyzing vast volumes of patient data to identify trends, anomalies and potential problems.

Artificial intelligence algorithms process data on patients' vital signs to establish personalized baselines for each patient, taking into account factors such as age, gender, medical history and current health status. Once these baselines are established, the AI system continuously monitors the input data for abnormalities. There are four key basic components that underpin remote patient monitoring systems using artificial intelligence algorithms (table. 1).

Table. 1. Key components of a remote patient monitoring system using artificial intelligence algorithms

No.	Component name	The essence of the components
1	Near-real-time monitoring	Wearable devices and sensors equipped with artificial intelligence technology continuously collect patient data, ensuring a constant flow of information. This allows artificial intelligence algorithms to detect even the smallest deviations from established baseline patient indicators
2	Pattern recognition	Artificial intelligence models are able to recognize patterns efficiently and quickly. By analyzing patterns in the collected data, such as irregular heart rhythms, sudden spikes or drops in vital signs, and sudden changes in activity levels, AI can detect potential signs of poor health that might otherwise go unnoticed without the use of an algorithm
3	Anomaly detection	Artificial intelligence algorithms are trained to detect anomalies that fall outside of normal variation. When an abnormality is detected, the AI system alerts healthcare providers, allowing them to immediately intervene and take action immediately
4	Predictive analytics	In addition to detecting current abnormalities, AI can also predict potential health problems based on trends and historical data. For example, if a patient's heart rate variability gradually decreases over time, AI can alert healthcare professionals to an increased risk of heart problems

It should be noted that the use of remote patient monitoring systems has quite serious advantages over classical monitoring tools, among which the following can be recalled:

1. Better management of chronic diseases: patients with diseases such as diabetes, hypertension and heart disease can benefit greatly from RPM. By regularly monitoring their health, patients and their healthcare providers can identify potential problems before they become serious.
2. Improved Convenience: with RPM, patients can manage their health from the comfort of their homes. This eliminates the need for frequent visits to the doctor, saves time and money.
3. Increased peace of mind: for many patients, RPM provides a sense of security and control over their health. They can monitor their own progress and be alerted to potential problems, giving them a greater sense of autonomy.
4. Improved Outcomes: patients using RPM have better outcomes overall. They are more likely to achieve their health goals and experience less complications from chronic diseases [20].

Thus, remote monitoring of patients, as well as systems developed on the basis of this method, have significant prospects for improving patient care, but, unfortunately, its implementation also faces significant technical problems. To fully realize RPM's technical potential, issues such as data management, sensor accuracy, system compatibility, and user adaptability must be addressed. Collaboration between healthcare providers, technologists, and IT teams is essential to overcoming these barriers and advancing the field of medicine.

Conclusions and prospects for further research.

Therefore, the implementation of remote monitoring of patients in Ukraine has several problematic issues, the main ones being the vagueness of the legislation, technical problems, low level of awareness of medical workers and mistrust of patients. In order to solve the problems with the legislation, it is necessary to initiate a change in the current law on the provision of medical services. To solve technical problems, it was proposed to use artificial intelligence algorithms and integrate a limited set of monitoring devices. To solve the problem with the insufficient level of awareness of employees, it is necessary to improve their training in educational institutions by creating a separate course on the basics of remote monitoring of patients. Patient trust can be gained by explaining the benefits to them of using remote monitoring systems, in terms of convenience and time savings. In the following studies, it is necessary to concentrate on the issues of implementation and construction of a system of remote monitoring of patients in an already existing medical institution.

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