Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 3 (2023)

Enhancing Healthcare Delivery: AI Applications In Remote Patient Monitoring

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Abstract: Research in Remote Patient Monitoring Systems (RPMS) is highly valued since it directly impacts people's health and wellbeing. The number of cases being treated with RPMS has increased since the beginning of the pandemic. However, there are still challenges to be met, such as mobility, heterogeneous networks, standardisation of RPMSs, automation, and Quality of Service (QoS), despite the rise in their use. The incorporation of artificial intelligence (AI) into remote patient monitoring (RPM) is causing a revolution in the healthcare industry by improving the quality of care provided to patients, boosting operational effectiveness, and making it possible to intervene earlier. RPM makes use of technology to monitor the health of patients in a remote location, hence minimising the frequency of in-person visits that are required. The addition of AI algorithms further enhances the potential of RPM by analysing huge volumes of patient data to identify patterns, abnormalities, and potential problems. In this study, we will investigate the most potentially game-changing applications of AI in remote patient monitoring in 2023 and beyond.

1. **Introduction**

The increasing incidence of highly contagious diseases like COVID-19, the shift in demographics towards an ageing population, and the rise in the total number of health problems have all led to the development in the number of remote patient monitoring systems (RPMS). Additionally, as a result of advancements in technology, the utilisation of RPMS has been more widespread in recent years. Patients who suffer from certain situations, such as those who have chronic diseases, infectious diseases while they are isolated, and patients who have mobility challenges or other constraints, are the primary focus of RPMS [1]. individuals recovering from surgery, babies, and elderly individuals are also candidates for treatment with these devices. The purpose of healthcare is to provide patients with as much relief from the discomfort that they experience in their daily lives as is humanly possible. Patients consequently have the ability to walk around freely and exercise in a setting that is completely private [2]. In the past, patient monitoring systems often consisted of wired sensors that were directly connected to computers located within hospitals. The mobility of the patient was severely limited as a result of these systems, which was one of its major drawbacks. The equipment that was employed was not only cumbersome and pricey, but it could only monitor a small number of patients at a time. RPMS came into use when healthcare facilities started offering home-based care, which led to their expansion of those services. This technology, much like older methods of patient monitoring, was not very user-friendly. Researchers have been able to develop methods for wirelessly connected patient monitoring, as well as methods for monitoring patients remotely, since technology improvements have made it possible for them to do so throughout time. An ever-increasing number of researchers and organisations are utilising remote patient monitoring systems to improve patient care, and the market for these systems is rising at a rapid rate [3]. This is helping the health industry make great advances towards improvement, which is a positive development.

Physiological data is gathered by means of biomedical sensors in a system called remote patient monitoring in order to assess patients' states of health outside of the context of a hospital [4]. People's homes, the places they currently live, work, and play, are destined to become new therapeutic communities. The acquired data is subsequently transmitted wirelessly to the healthcare practitioner for use in making the necessary decisions [5]. Heart rate, respiration rate, temperature, blood pressure, and oxygen saturation in the blood are just some of the physiological measurements that may be taken and relayed with the help of telehealth.

RPMS have the advantage of being able to monitor patients' health states continuously and diagnose sickness in real time, which is a distinct advantage. It is imperative that immediate action be taken in the event that premature deaths are discovered. In addition, the use of various communication technologies helps these systems bring down the overall cost of providing medical treatment. While receiving therapy, a patient is still able to take part in their typical day-to-day activities. In addition, the RPMS enhances both mobility and emergency care in the event of a traffic collision [6].

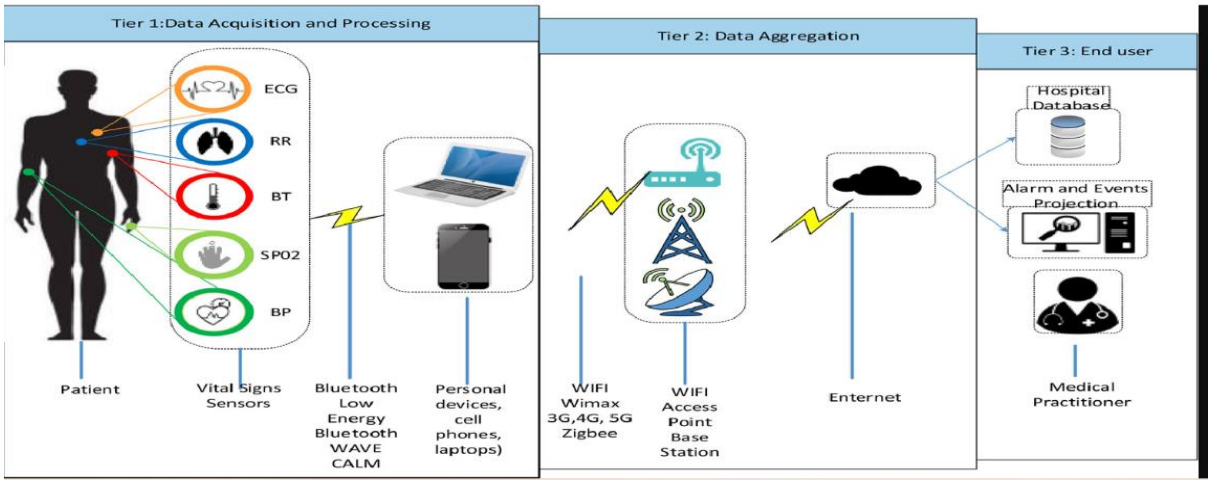


Fig. 1: Outline of a Sample Remote Patient Monitoring System

During the process of remotely monitoring patients, data can be acquired by using wireless sensors as well as wireless communication. This data is then transmitted to the hospital. During the process of data collecting, a variety of sensors, including contact-based ones that can be worn or implanted and non-contact ones, are utilised. The acquired data can be processed and changed to a suitable form using an internal or external controller before being wirelessly transmitted to the hospital. The data can be transformed in this way before transmission. Depending on the type of connection used, data can be transferred either over small distances or over great distances [7]. Tele-health services will typically progress through the three stages of communication networks shown in Fig. 1.

2. Literature Review

The medical care business is continuously looking for novel approaches to increase the quality of patient care as well as monitoring. There has been growing recognition in recent years that a solution could be found in the integration of AI and the IoT. AI is short for artificial intelligence, and it defines the potential of computers to replicate human intelligence by carrying out activities such as data analysis, pattern recognition, and decision-making. The Internet of Things (IoT) is a system of interconnected, internet-enabled gadgets that can exchange and process data. They can be combined to allow for real-time monitoring, preventative therapies, and individualised patient care, all of which have the potential to revolutionise the healthcare system [8].

Healthcare providers have traditionally depended on time-consuming and error-prone manual processes to collect and process data. This has opened the door to the possibility of errors as well as delays in the provision of care to patients. The healthcare system has the potential to be turned into a linked ecosystem that allows for data to be collected, analysed, and acted upon in real time with the help of AI and IoT [9].

This synergy allows for round-the-clock tracking of a patient's vitals, medication compliance, and behavioural patterns. Healthcare experts are able to make more precise diagnoses, better forecast how a disease will proceed, and develop more individualised treatment regimens when they tap into the power of AI algorithms. The potential of AI and IoT to create insights from massive amounts of patient data is one of the primary benefits offered by these technologies in the medical field. Data from sources such as electronic health records (EHRs), medical imaging, and wearable devices can be overwhelming and convoluted to make sense of [10].

Artificial intelligence systems can examine the data and find connections and patterns that aren't immediately visible to human eyes. For example, machine learning algorithms can be trained to detect the first warning signs of a patient's condition deteriorating by monitoring the changes in the patient's vital signs over time [11].

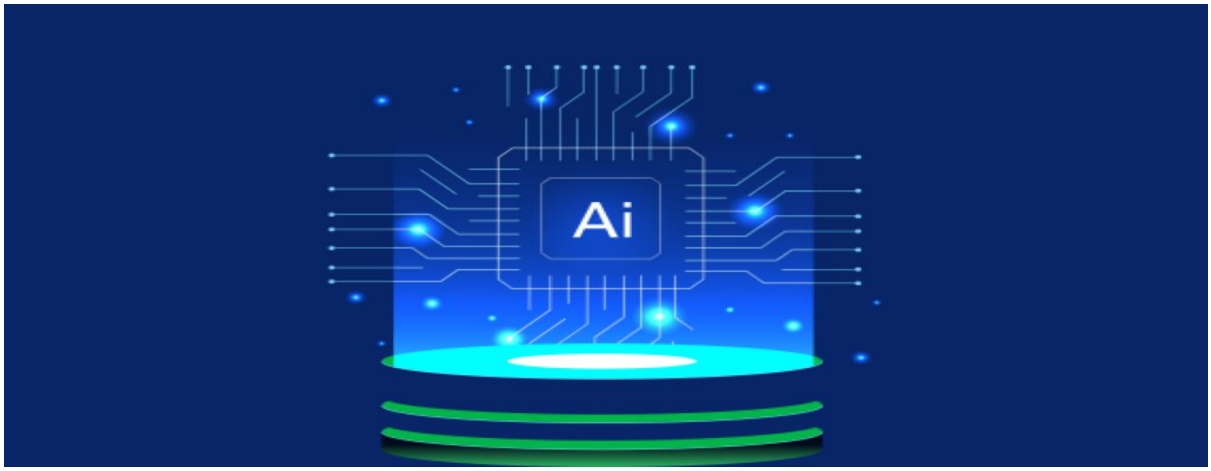
Ethical considerations, including as bias in AI algorithms and the appropriate use of patient data, must also be addressed to maintain trust and transparency. Additionally, Internet of Things technology, such as wearable sensors, intelligent medical devices, and remote monitoring systems, allow for continuous, real-time monitoring of patients' vital signs. These devices are able to monitor a variety of parameters, including vital signs, medication compliance, levels of physical activity, and sleep patterns, among others. Data collected by IoT gadgets can be delivered to a centralised hub, where intelligent software can process it for useful insights and warnings [12].

Early intervention thanks to this preventative strategy of monitoring patients can reduce the likelihood of negative outcomes and the frequency with which patients must be readmitted to the hospital. However, there are challenges associated with implementing AI and IoT in healthcare, including data privacy and security concerns, ethical considerations, and uncertainties about system interoperability. It is of the utmost necessity to establish a happy medium between exploiting the potential benefits of new technology and maintaining the confidentiality of patients' personal information and medical data. In summing up, the application of AI and IoT in healthcare presents a significant opportunity to realise improvements in patient treatment as well as monitoring [13].

Artificial intelligence and the internet of things have many applications in healthcare, including but not limited to patient monitoring and diagnosis. In addition to this, these technologies have the potential to improve patient participation and empowerment. Patients can receive personalised information via chatbots and virtual assistants powered by AI, have their questions answered, and receive assistance and direction from these technologies [14]. In addition, AI algorithms can investigate the patient's preferences as well as the patient's medical history in order to produce personalised treatment plans and suggestions.

issues regarding privacy and security continue to be prominent [15]. These issues include the protection of patient data as well as the reduction of the danger of unauthorised access. In order to achieve seamless data integration, it is essential to ensure interoperability and standardisation among the various systems and devices that make up the internet of things. In addition, the maintenance of trust and fairness in healthcare practises requires significant attention to be paid to ethical aspects such as the transparency of artificial intelligence algorithms and the responsible use of data.

3. Incorporating AI Into Rpm For Improved Patient Care



The past ten years have witnessed a meteoric rise in the number of data pertaining to healthcare, with the healthcare business responsible for producing thirty percent of the total volume of data in the globe.

Recording data in real time and combining it with information from other clinical, administrative, or contextual sources is a powerful tool for supporting RPM. However, this strategy can only be successful if the analysed digital data can be turned into insights that can be put into practise.

In order to assess and make sense of the hundreds of data points generated daily by patients, the healthcare sector has begun adding artificial intelligence (AI) into RPM systems. Despite the fact that technology is still in its infancy, 23% of healthcare CEOs in the US believe that AI and ML are very effective at improving clinical outcomes because of the following key strengths:

- **Real-time patient health monitoring:** The ability to perform real-time patient health monitoring, which can result in the earlier detection of potential health problems, is a key strength of RPM when combined with AI. AI-enabled RPM can keep a constant eye on a patient's vitals, medication compliance, and other key health indicators, alerting doctors to issues before they become catastrophic.
- **Better chronic condition management:** The ability of healthcare providers to effectively manage patients with chronic illnesses is yet another advantage of RPM combined with AI. With the use of AI, medical professionals are able to monitor a patient's progress, recognise any possible health problems, and make any necessary adjustments to the patient's treatment plan. This makes hospitalisation for the patient unnecessary.
- **Patient-owned care:** RPM that is powered by AI also makes it easier for patients to control themselves, which enables individuals to take charge of their own health and wellness. Patients are able to make more educated decisions and have more productive conversations with their healthcare professionals when they are able to monitor their health remotely. This ultimately leads to improved health outcomes.
- **Reduced hospital readmissions:** Even beyond the mundane benefits of day-to-day life, RPM with AI offers a variety of advantages. Some RPM systems that are powered by AI can assist reduce hospital readmissions by simplifying the process of monitoring high-risk patients and reducing the number of unnecessary trips to the emergency department. Therefore, when RPM systems are deployed on a large scale for these emergency conditions, not only will they reduce the significant spending on healthcare that occurs in emergency departments in the United States, but they will also make a significant difference in whether or not patients live or die.

There has been a revolution in the precision and efficiency of healthcare delivery brought about by the application of AI in remote patient monitoring. The results for patients have improved because of this, especially those with neurological and cardiovascular diseases. To rephrase, AI is making it possible for RPM systems to greatly enhance health equity and patient access in ways that were before impossible.

4. Pioneering Uses Of AI In Remote Patient Monitoring

Despite the fact that research on the applications of AI in speeding RPM is just getting started, many healthcare providers are finding that these technologies have become indispensable tools. The use of artificial intelligence has opened the door to an unprecedented number of potential applications for remote patient monitoring.

- **Vital Signs Monitoring:**

The vital signs monitor is a crucial piece of equipment that aids the medical staff in taking accurate, real-time readings of the patient's physiological data. It measures blood pressure both noninvasively and invasively, in addition to analysing an electrocardiogram (ECG), heart rate, pulse oxygen saturation, respiratory rate, and temperature.

These monitors have the potential to be modified into wearable gadgets if artificial intelligence is incorporated into the process. The AI-integrated vital signs monitor that was only recently released by VitaSensors serves as a prime example, displaying its capability to understand patient data and convey the information to physicians for the purpose of fast decision-making.

- **Physical Activity Monitoring:**

Monitors of physical activity have been used for a long time to quantify the amount of energy used during physical activity in particular units (for example, kcal/d) or other metrics related to body mass. These devices are also helpful in tracking patients' day-to-day activities (such the number of steps they take on a daily basis, for example) and classifying those activities according to the level of intensity or the body posture.

These monitors now have access to essential tools that allow them to go beyond the capabilities of standard activity tracking. These AI algorithms are able to analyse and categorise the behaviours of patients according to the level of intensity or body posture, and they can also trigger emergency warnings. Take, for example, the fall-detection function, which is an AI-enabled functionality that is widely utilised by a variety of industry giants, including Google, Apple, Samsung, and others.

- **Chronic Disease Management:**

Remote patient monitoring (RPM) has risen to prominence as an important tool for the management of chronic disease due to the expansion of virtual health care. RPM has profoundly changed the landscape of the management of chronic diseases by providing continuous health tracking outside of the boundaries of a clinic. When combined with AI, the management of patient data by healthcare professionals becomes more simplified, which boosts the chances of RPM in terms of finding remedies for chronic diseases.

Take, for example, the incorporation of RPM into the monitoring of drug adherence, which is an essential component in the management of chronic diseases. In this context, generative AI acts as a virtual companion, dispatching thoughtful reminders and notifications to increase patient engagement.

In addition, increased levels of adherence make it possible to collect data more frequently and with a higher degree of precision, which paves the way for advances in the healthcare sector. Currently under development, AI-enabled Decision Support Systems (DSS) are a useful tool with the potential to improve patients' management of serious, long-term conditions like stroke, diabetes, and hypertension.

Traditional RPM also has trouble keeping up with the complexities of tracking mental health issues including schizophrenia, bipolar disorder, and suicidal ideation. Here is where the use of generative AI and ML in healthcare has the potential to open up new avenues for the study of human behaviour, better informing physicians about the course of their patients' mental illnesses and allowing them to offer more tailored recommendations for care.

- **Emergency Monitoring:**

Integrating AI with RPM is beneficial in more ways than one for patients. Additionally, it might be of great use to those who work in the medical field. RPM that has been augmented with AI is now able to provide assistance with clinical judgements and reduce the strain placed on overworked emergency departments. The most common use of AI assistance has been in the triage procedures of emergency departments. This helps to categorise patients according to the severity of their conditions, which in turn enables prioritisation.

- **Facial and Emotional Recognition:**

With the help of artificial intelligence (AI), a new technology known as facial and emotional recognition can now detect patients' emotional states as well as their heartbeat levels by using face recognition

algorithms, heartbeat sensors, and temperature monitors. The deployment of an RPM system driven by AI of this kind will improve our ability to identify and comprehend human emotions that point to a deterioration in a patient's health.

The potential of RPM that is powered by AI is only just beginning to be realised, and there is little doubt that it will continue to develop over the course of time. RPM is expected to enter a new phase during which patients will be able to obtain great care regardless of where they are located in the world as more healthcare professionals use this technology.

5. Conclusion

The application of AI is bringing about a revolutionary shift in the delivery and reception of healthcare in light of the current situation of the healthcare system around the world. RPMS are indispensable to our day-to-day lives. This has been demonstrated by the progress that has been made in RPMS technology. The analysis of RPMS that was conducted for the purpose of this paper focused on four distinct aspects: the applications, structures, methodologies used, and issues faced. RPMs have a place in the treatment of disabled persons, infants, and the elderly. Some of their structures are wearable while others are non-contact, and they have revealed both. Some of the challenges faced by RPMS include throughput, network lifetime, quality of service, and energy efficiency. It was proposed that these issues may be addressed with the help of Markov models, game theory, mobility models, cooperative communications protocols, and routing protocols.

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