A Remote Patient Monitoring System: Need, Trends, Challenges And Opportunities

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Abstract: This study was conducted to understand the need, challenges and opportunities of Remote Patient Monitoring System (RPMS). To make any country as a developed nation, many essential factors on which government should have to focus and improve the services in the rural areas as well as in cities like education, roads, shelter and food. If these requirements could not be fulfilled, then this will raise the health-related issues. The government should build a healthcare system which will reach to every individual, but to provide healthcare facilities to every individual physically not possible, therefore, there is a need for Remote Patient Monitoring System. The literature review is helpful to understand the importance of RPM Systems and its implementation in large-scale and delivering quality healthcare services to patients.

Index Terms: Machine learning, Healthcare, Wearable sensors, Remote Monitoring, Internet of Things. Patient monitoring, Security

1. INTRODUCTION

Due to modernization and urbanization, the majority of people are migrating from rural areas to urban locality. This scenario has resulted in the increasing population of the cities daily and as compared to the growth; there is a need of improvement in the HealthCare System for maintaining the hygiene of all people[1]. Now consider the example of all classes of the people. Firstly, the higher-class people or the elite population, if they are prone to any health-related problems like any chronic diseases, then they can afford to pay a large amount of money for their treatment. However, unfortunately, their count is very less as compared to the whole population. Next comes the middle-class people. When they visit any nearby healthcare centers, there are chances that they will, fortunately, get adequate treatment at the proper time. However, mostly, what happens is that due to the lack of infrastructure, doctors, medical equipment's, the patients need to be transferred to different hospitals. This is the wastage of very crucial time for the treatment of the patient, and it may increase the loss of lives of numerous patients. Now, the remaining class of people who cannot afford such expensive treatment, and due to lack of knowledge, there may be chances of spreading of the diseases. So, various scientists and engineers have been researching for this crisis, and they have come to a solution to the remote patient monitoring system and predictive diagnostics.Due to the increasing elderly population, lack of expert clinicians and decidedly fewer hospital facilities and very high cost involved in travel for patients as well as medical persons these parameters are forced to think about remote patient monitoring and early disease identification.

Remote patient monitoring (RPM) has improved the doctor's ability to monitor the patient from a remote location without using clinical environment. RPM uses various wearable body sensors [2], biosensors to gather individual's health-related data from any place and this data is transferred through the Internet to doctors and clinicians who are available everywhere for assessment and recommendations [3]. Due to exponential growth in sensor technologies have promoted the use of the Internet of Things [4]. Now a day's chronic diseases increase health care costs, and it also reduces working efficiency of human beings [5]. There are various chronic diseases which impact national health care budgets[6]. Current technologies like the Internet of Things, Machine learning and sensor devices must be utilized to improve the patient's health, to provide quality of care, to enhance clinical services at a remote place and to reduce the high cost involved in it end[7].

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2 The Need of Remote Patient Monitoring System

2.1 Inadequate specialist doctors and health care services

As per the Rural Health Statistics (RHS) 2017 report, primary health care in India was falling short of providing essential health care services for the growing population. All the health care infrastructure is inadequate in condition and lacking to provide necessary and critical facilities, specialized doctors, health assistants to rural patients [8]. In another study, authors also claim that by 2030, India requires around 20 lakh doctors to satisfy the norms specified by WHO 's standard that is1:1000[9]. The CHCs in rural India are functioning without the doctors. As per the authors, almost 82% of the specialist's posts in the CHCs are unoccupied. As per the CHCs Norms in India, four specialists', surgeon, physician, gynecologist and pediatricians per CHC is necessary to provide healthcare services. RHS 2017 likewise expresses that there is an absence of 87% surgeons, 74% gynecologists and obstetricians,85% physicians and 81% pediatricians in the CHCs in rustic India [8].As per the Rural Health Statistics (RHS), there was a need of 6,430 primary health centers (PHCs) and 2,188 community health centers (CHCs) in India[10] and around 800 rural hospitals and 807 PHCs were running without a single doctor. In a rural area, PHCs are the preliminary contact point between villagers and medical officers. They provide medicinal; protective, and other health-related services to rural Indians. Now total 25,743 primary health centers are running across India, and there is a shortfall of 10,112 female health assistants,15,592 male health assistants and more than 61,000 health workers[11]. The status of Community Health Centre (CHCs), which considered as referral centers for four neighboring PHCs to provide necessary specialized health-related services. There is a need for 2,525 CHCs across India [10], and only 5,117 dedicated

doctors are working in these CHCs. The article published in the Indian Journal of Public Health states that , India, need 2,070,000 doctors [12]. The current status of rural health care facilities is the dominant force to think about Remote Patient Monitoring System.

2.2 Rapid growth in elderly people

As per another study published by IRIS Knowledge Foundation in collaboration with UN-HABITAT by 2020, India becomes the world's youngest country. However, after that, the number of elderly populations will rise significantly. Another study published by Help Age India, claims that the population of older adults will reach around 143 million and two-thirds of elderly people live in a rural area where there is lack of necessary and minimal health care facilities. Therefore, there is the necessity of remote health services in rural areas. If Remote Patient Monitoring System is implemented successfully at remote places, it will be easy for clinicians to monitor the real-time status of patients and give health-related advises and medicines to take. It also reduces the travelling cost of patients as well as clinicians as it provides services to the elderly patient's doorstep[13]

3 DRIVING FORCES TO PROMOTE THE USE OF REMOTE PATIENT MONITORING

Now a days, everyone wants continuous preventive care outside the hospital. More than 500 companies and health care service providers are working on developing new devices and products to reduce readmission rates, travel cost and to provide services at a remote location.

3.1 An increasing percentage of chronic diseases and the elderly population

As per the World Health Organization, the world population of ageing people increased exponentially. By 2050, the world's population aged sixty years and older is predicted to be more than 2 billion. The ageing population suffers from many chronic, and that increases the burden on health care services. To handle this issue, require a specialist and diverse health care workforce that treat patients effectively in any complex medical conditions [14]. This is the main driving force to think about the use of Remote Patient Monitoring System.

3.2 Wearable healthcare Devices

Advancements in the technology and rising health awareness in people boosted the use of smart wearable devices. These wearable devices play a very vital role in healthcare industries to monitor and track the patients. As per the market research report, the global healthcare market expected to expand at a CGPR of 22.07.0 % up to 2023[15]. Technical advancement in the field microelectronic fabrication, it becomes easy to integrate sensors, it is signal processing system and digital processing circuits on a single chip at little cost.

3.3 The emergence of the Internet of Things

Internet impacted and changed every field. Moreover, now the increasing use of the Internet of Things (IoT) will change everything. IoT will allow healthcare service providers and patients to work together for chronic disease management and for monitoring continuously. Various IoT enabled medical devices are available now in the market, which is used to retrieve real-time data of the patient, and it helps for curing diseases and for preventive care[16-18].

3.4 Role of Machine Learning in Healthcare

Wearable devices are used to retrieve continuous data of patient health, and it grows exponentially. Processing and analyzing these vast datasets are a complicated task, and it requires more time for human being and sometimes it is beyond the scope of human capability. Machine Learning can process massive data and convert it into clinical information that is useful for specialist doctors to plan and provide preventive care to patients. Machine learning ultimately gives better outcomes than any traditional process, it reduces costs of care, improve the doctor's ability of analysis, and it leads to increased patient satisfaction [19-21].Machine learning impacting the medical field by helping in disease identification and diagnosis. Google developed a new machine-learning algorithm to detect and identify cancerous tumors on mammograms. Stanford made a new software system to detect skin cancer by using deep learning algorithm. Machine learning useful in fields where large image datasets are generated such as radiology, cardiology and pathology. Machine learning increases accuracy and reliability in pathological processes [19-21].

4 RELATED WORK

As indicated by Naresh Vemishetty et al., there are numerous devices and answers for remote Electrocardiogram devices which regularly face issues like huge peripheral expense per included sensor, not consistently coordinated with other smart home applications, and so on. In this way, they have proposed a remote wearable ECG monitoring system embedded in an IoT stage that coordinates different hubs and applications. It comprises of the two models with incorporated front end and models acknowledged with off-the-rack components This improves ease of use, cultivating market entrance, mix with other brilliant home systems through a single IoT framework committed to long haul monitoring of clients in special conditions without help. Non-specialized clients can likewise utilize it. There are favorable circumstances dependent on a various level as at framework level this system can be converged with other biomedical systems given IoT, at nearby sending level system can screen numerous patients with the same remote foundation which decreases by and significant expense per quiet. Unpredictability, the minor expense of including tolerant. Single ECG sensor has high sign quality and low power consumption [22]. Miranda et al. develop a system that consists of an open-source platform, which is a wireless gateway designed by using RF module as a base station and innovative hardware along with the user interface. It helps for universal recognition and identification platform (CRIP). Gateway system provides communication between patients, doctor, nurses, etc. The designed CRIP system and wireless gateway integrate different technologies, which helps to identify patients and medical devices and also enable us to use other Bluetooth medical devices[23]. They were tested using radiated EMC immunity testing to check developed wireless gateway technologies can be used and operated safely in medical environments or not. The developed system is affordable and easy to wear, which helps patients to accept it as home healthcare technology. There are not many issues which incorporate security and unwavering quality, the potential for bottlenecks, and the sending of bound together remote system arrangements which are required to interface portable clinicians. While from seller rivalry it results to bring down item cost. Difficulties in telemedicine innovation are to

create and acquaint data innovation to improving the quality and effectiveness of medicinal services.[23].Alshurafa et al. worked on Women's Heart Health Study (WHHS).They have developed Wanda-CVD, where participants are provided training for healthy lifestyle education. Then it is followed by six months program of technical support and reinforcement[24]. This prediction tool proves to be beneficial to people like clinicians, scientists to identify which participants are being benefited from this Remote health monitoring (RHM) system. They also show improvement in prediction. It analyses both contexts in the first month of intervention data and baseline features to demonstrate various aspects of proper diet consumption of young women of ages from 25 to 45. In this, they have made an enhanced RHM system, Wanda-CVD, i.e. used to identify cardiovascular disease risks, assist in reducing such risks[24]. Developed RHM system is a Smartphone-based and provide wireless coaching using feedback and prompts as social support. And this is a cost-efficient framework for analyzing features, first-month intervention data, to predict a reduction in the risk factor of CVD. They identify individuals 'unique characteristics and collect them during the first-month intervention. There are few advantages of RHM system such as decreasing hospital cost, minimizing clinician time, improving quality of care, targeting therapies save participant time and resources, etc. Their study was for an urban setting and not for the entire population. It needs to be used more in a diverse group of black women[24]. Triantafyllidis et al. presented a framework to develop sensor-based monitoring, which supports the diagnosis of health and avoid significant complications while maintaining patient well-being. The presented framework based on a service-oriented architecture, and it includes various types of sensors and mobile devices. It enables communication between physiological sensors by incorporating Bluetooth protocol to exchange data. Different design principles are covered as system extensibility, interoperability, personalization to provide better functional features and monitoring services, used by both patients and HPs in a remote health monitoring system.The drawback of these systems is Such systems are difficult to use, extend and sustain[2].Uddin et al. proposed a tier-based End-to-End architecture that has a Patient-Centric Agent(PCA)to monitor the patient continuously. In their system, data is inserted into the personal blockchain, which does data sharing among health care professionals and integrates into electronic health records. PCA manages multiple block chains for the same patient, and the modification of each block with a prefix tree to minimize energy consumption and incorporate secure transaction payments. The blockchain components preserve privacy during data collection from wearable body sensors. The architecture establishes a Body Sensor network by incorporating Smartphone(Sensor Data Provider), Patient Centric Agent, Blockchain, and Healthcare Provider Interface[25]. Security and privacy issues are handled by using PCA based End to End architecture, Lightweight encryption and authentication. The less power consumption of devices and lightweight communication protocol makes it more adaptable. Sometimes infrastructure failure, operational errors and wrong data routing may create problems[25].Prabal Verma and Sandeep Sood have presented the remote patient health monitoring system for smart homes. They used the concept of fog computing to develop an intelligent gateway. They focus on the connecting network using the gateway in-home and hospital use. They incorporate different advanced techniques for data mining and services such as notification services and distributed storage at the edge of the network. They also introduced Event triggering-based data transmission methodology along with temporal mining[26]. It delivers more effective patient sensitive information to end-users, in this quick processing is done with minimum delay, reduces the amount of data, temporal health index can be calculated to define the urgency of the situation, high accuracy and response time. Fog computing is used to reduce the problem related to location, high latency and reliability. As compared to fog computing IoT based Remote Health Monitoring is considered better because they are high efficient and deliver time-sensitive information to the clients[26]. Jemal H. Abawajy and Mohammad Mehedi Hassan presented pervasive patient health monitoring (PPHM). For explaining this, they have taken reference to real-time monitoring of heart failure patient. PPHM is based upon integrated cloud computing and the Internet of things and wireless technologies for efficient remote patient health status monitoring system. Working of this system is as sensors collect essential data and send to the personal server. When a request is generated, from the authorized person such as a nurse, patient, doctor then on-demand monitoring is performed. Their proposed system is flexible, energy-efficient, scalable, excellent patient care through proper clustering and classification of data; effectiveness is shown by performance analysis, continuous monitoring is performed[27]. They have currently implemented the proposed algorithm, and they are still testing in a real environment. J. R. Cuevas et al. proposed a telemonitoring system for patients with chronic kidney disease who are undergoing peritoneal dialysis. They also provided an android app for the patient and medical staff on which patients records his/her dialysis baths and other relevant information, and at medical staff side there is mobile web app where they can monitor patient progress and current condition and also provide a recommendation if any to improve the condition. The presented system takes continuous review on disease control and monitordata record through any of session. It also provide two alerts by detecting biomedical indices set by the doctors CAPD (Continuous Ambulatory Peritoneal Dialysis) and APD (Automated Peritoneal Dialysis). There is the facility of sending auto generated email why warning occurred. Medical staff can generate a report and query any record by using this system[28].According to Sathya et al., when in remote health monitoring system data is transmitted from patient to doctor or vice versa then there are chances of data loss, or used by an unauthorized user, susceptible to attacks, so security Algorithms are used. Before using, they are compared to check which algorithm is well suited in which situation. In blowfish encryption data generated is transferred to the doctor's digital assistant. From the diagnostic center, it is checked by a doctor, nurse, etc. In attribute-based encryption algorithm is implemented over the network. If the emergency is their then doctor can take immediate actions like sending an ambulance or sending medical people to the patient's location to save the patient's life. The presented system also shows a graphical representation of encryption and decryption time. The drawback of this system is, if we use a single symmetric key algorithm, then it is less secure[29].Spano et el presented personalized remote cardiac health monitoring system based on a mixed-signal system. They allow complexity system with on board processing methodology, preceded by allowing

power analog module targeting remote and personalized CVD monitoring. There are four folds used to find the boundaries of ECG signal, a low power AFE, and complexity architecture of ECG feature extraction by reusing the same module. Thismethodology reduces the power consumption of the chip and noise levels are within desired specifications. The presented system is efficient to detect abnormal ECG waves[30].Alexander Sunet al. demonstrated reconfigurable, multi-technique electrochemical biosensor platform for mobile devices and wearable technologies. The biosensors are capable reconfigure itself into three estimation modes to perform amperometric, potentiometric, and impedance spectroscopic tests all with insignificant excess gadgets. Some wearable devices have fitness-oriented sensors for tracking physical activity, ECG, PPG, etc. [31]. Advances in sensor miniature and portable electronic had made this easier. This enables remote and accurate personal health monitoring, which is suitable to use with mobile devices, blood glucose test, Lactoferrin, pH test, EIS, etc. For removing the disadvantages as large size and power of design, components can be reused in different measurements modes keeping performance and functionality of the module to be used in many POC applications[31].Yang et al. presented a wearable bio-sensing device with a facial mask for bio potentials monitoring, which is in up to eight channels. It is an IoT system for automatic pain assessment using facial expressions. It proves to be a wearable solution. It works on wireless sensor node, and IoT system, a cross-platform interactive web application is developed for real-time streaming of high-volume EMG data, digital signal processing, interpreting, and visualization, the cloud platform is used for communication between server and application. An alternative to the self-report method, useful for patients in the intensive care unit and minors, low power and miniaturized sensors are used with Wi-Fi data transmission. This system is comfortable and has low energy consumption. More work is required on online data analysis, decision making support algorithm using cloud platform[32].

5 THE PROPOSED SYSTEM

RPM system will be developed with monitoring devices, local processing unit or smartphone with Internet and Bluetooth connectivity and secure cloud storage system with machine learning analytics. The doctor sets up upper and lower limits for such crucial measurements as blood pressure, blood glucose, body temperature, oxygen saturation and pulse. The patient is observed for variations from the norm in these measurements at whatever point a vitals perusing is recorded through the framework. Without fail, a crucial sign crosses a threshold (upper or lower limit) and goes outside the set range, a moment caution is activated in the RPM system, and it conveys an SMS to the doctor, advising him/her that the threshold value has been crossed. Then the RPM system has predictive diagnostics, which will help the doctor and patient to identify the diseases and suggest various possible medicine and treatments. The Fig.1 illustrated the Remote Patient Monitoring System in details.

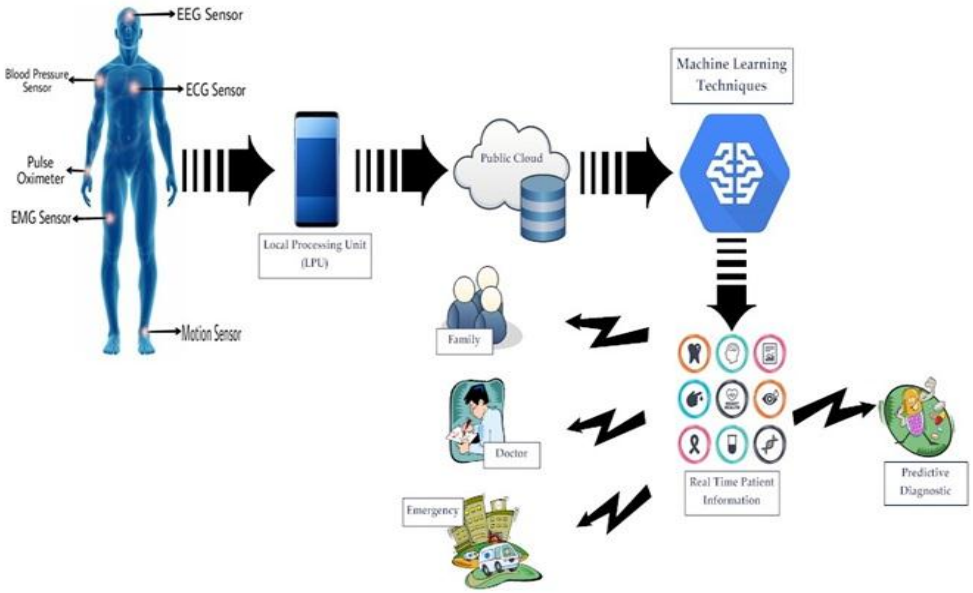

Fig.1 *Proposed Remote Patient Monitoring System*

6 CHALLENGES TO USE REMOTE PATIENT MONITORING SYSTEM

After experiencing a valid medical procedure or surgery at a doctor's facility, a patient gets discharge from the hospital. Then after a few days, they again readmitted due to care is not appropriately taken at home after surgery. Such type of cases occurs 20 per cent time which frustrating patients and their families, doctors and hospitals. Remote Patient Monitoring (RPM) reduces the readmission rates and also it makes health care services cost effective. However, using RPM have various challenges because there is no medical staff available to ensure the proper use of the system. To make Remote Patient Monitoring System more usable, all problems must be addressed. Main challenges are:

6.1 Connectivity and availability of Network

The RPM systems are dependent on network connectivity and its continuous availability at patients and doctor premises.

Wearable devices transmit data over the network continuously if it interrupts it hampers patient's health and the diagnosis. For example, heart patient requires continuous care and monitoring [34], if network availability is not there, the patient data will not reach to the doctors and family members at the correct time [35].

6.2 Sensors, wearable devices and its wear ability with comfort and convenience

RPM systems are totally based on sensors and wearable devices. These devices must be available as per the patient requirements, and these should be comfortable to use and have low cost. Wearable devices must be energy efficient, low-weight, patient-friendly and easy to use[35].

6.3 Security and Privacy

RPM system work on networks availability, all the networks are susceptible to hacking and their security issues. RPM system must be incorporated with various security measures to provide a guarantee about data confidentiality and privacy of a patient's records [35].To accept RPM system widely there are various common issues like cost and affordability, data manipulation and violation of patients' rights, scalability, the accuracy of data, data authentication, dependability, secure localization, accountability and flexibility of [36].

7 Discussion

Considering the increase in population and subsequent growth in diseases, the need for better medical facilities have risen to a considerable number. For the proper medical facilities and medication, the number of doctors and hospitals should be increased to maintain an appropriate ratio of patients to doctors. However, due to the abundant increase in diseases and the affected patients, it is essential to keep proper surveillance of the body of people to ensure their adequate health. Remote Patient Monitoring enhances the monitoring of patient vitals and health statistics outside of the actual clinic settings such as hospitals. Remote patient monitoring is such a technique that helps to create sync between the medical conditions of a patient with the doctor. It is a simple client-server model which uses electronic sensors to examine the medical condition and send it to the doctor located at a remote location. In this manner, the need of the face to face appointment of the doctor and patient is minimized as the doctor can keep a watch on the patients. This method uses specific electronic sensors which are installed in the gadgets that keep a tack on the physical state of the patient. The heartbeat, blood pressure, body temperature, etc. are detected using specific sensors and a report is sent to the doctors' machine automatically so that he can examine the patients' medical condition. For specific locations where medical support cannot be supplied, this remote patient monitoring system can be utilized as a valuable alternative to carry machinery to the patient location or to bring the patient to the hospital. It reduces the required number of medical staffs per patient as the electronic devices automatically do the physical examination. One of the critical benefits of Remote Patient Monitoring is the decreased cost of visits of the patients to the doctors, as well as greater availability for the appointments. Also, Remote Patient Monitoring helps patients and their family members feel comfortable knowing that they are being monitored and will be assisted if any problem arises in their health. The time required for examining the patients is thus saved as a result of Remote Patient Monitoring implementation, and it also increases efficiency and allows the medical examiners to spend more time in remotely educating and communicating with patients. Moreover, the data that is gathered about the patient can be used to study the patient's behavioral and psychological patterns. This data can be used to educate trainee doctors to make them familiar with the conditions of the patient in the current generation. This data can also be used to predict the future possibility of any disease or condition of the patient by examining their behavioral habitat. This, Remote Patient Monitoring can regularly assists the patient in maintaining his/her health and helping them in avoiding any irregular and unhealthy habits.

8 CONCLUSION

This article, we explain various aspects of Remote Patient Monitoring Systems. As the ageing population is proliferating, the necessity of Remote Patient Monitoring over the traditional hospital-centric healthcare system explained in detail. Afterword, we have discussed driving forces to use and challenges to accept this system is described. After surveying different RPM systems developed by other scholars, we concluded that only monitoring could be performed through these systems. We are developing an RPM system with predictive diagnostics and also handling different security and privacy issues associated with it. This study helps researchers and healthcare service provider to develop secure and reliable Remote Patient Monitoring Systems to handle various chronic as well as other diseases.

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