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Indigenous and Disruptive Remote Patient Monitoring Devices - A Case Study on AI in Healthcare

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Abstract

The evolution of Industry 4.0 technologies has facilitated the growth of technologically driven healthcare solutions, disrupting, and significantly challenging the way the sector works and moving towards *Healthcare 4.0.* The global interest in Artificial Intelligence (AI) in the healthcare sector is increasing tremendously in comparison to other sectors. A rapidly ageing population with increasing health complications has led to the rise of AI-driven Remote Patient Monitoring (RPM) devices, where a patient can be monitored in the comfort of a home, using the latest communication and sensor technologies. This study aims to understand the usage of Artificial Intelligence (AI) as a healthcare disruptor, capturing the ever-increasing demands concerning the remote patient monitoring industry, making huge improvements, and redefining the way how healthcare can be provided, for timely and cost-effective solutions. The analysis of these remote monitoring devices has been done through a case study approach. For this purpose, two AI-enabled remote patient monitoring devices Dozee.ai and Qure.ai, have been taken which have been assisting patients and doctors in the diagnosis of health vitals remotely. Data has been taken from secondary sources to analyze the concept of indigenous and disruptive innovations. Both the apps have been quite successful in their diagnosis of Covid positive patients and have assisted both patients and healthcare personnel during critical times. Despite the huge advantages of AI-enabled RPM devices, they are vulnerable to data hacking and privacy issues. Any errors in these devices can pose potential risks to patients' health.

Keywords: AI-Enabled Remote Monitoring Devices (RPM), Case Study, Challenges, Google Trends, Healthcare 4.0

1. Introduction

The healthcare sector has undergone several technological transitions in recent times, due to the development of smart technologies, including Artificial Intelligence (AI), the Internet of Things (IIoT), the Cloud, and Big Data. Healthcare 1.0 was characterized by the manual recording of patient data by clinicians. It transitioned to Healthcare 2.0 with the electronic storage of health records at the start of the 21st century; Healthcare 3.0 saw the increased use of wearable technology, such as trackers and smartwatches (Hathaliya *et al.,* 2019). The advent of smart technologies in recent times has brought forth a new era of interconnected and intelligent health care, i.e., Healthcare 4.0 (Li & Carayon, 2021). Healthcare 4.0 in contrast to the previous generations, uses a huge number of networked devices, connected via the Internet of Things (IoT) and Cyber-Physical Systems (CPS) to monitor a patient's health parameters, and perform several essential health-related functions, according to Hathaliya *et al.* (2019). Numerous wired

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and wireless equipment, sensors, and gadgets are being used in hospitals and homes, where enormous volumes of data are generated continuously (Rehman *et al*., 2019). The old "patient-doctor" paradigm has changed significantly due to the development of medical wearables, with computers and sensors automating various processes, speeding up diagnosis and treatment, and enabling people to self-monitor their health performance (Rehman *et al*., 2019). This has led to the development of numerous patient monitoring systems and gadgets that help with the early diagnosis and treatment of a variety of ailments (Alcaser & Cruz-Machado, 2019).

The innovative use of AI in the healthcare industry is assisting radiologists and pathologists to detect illnesses quickly and accurately by using algorithms for the automatic compilation of reports, improving accuracy, and productivity, and freeing up their time. Health 4.0 is the integration and incorporation of cutting-edge techniques according to patient requirements to produce high-quality, highly customized, real-time, data-regulated medical devices (Javaid & Haleem, 2019). Machine-based health monitoring systems have become the focal point for many industries and researchers in recent times (Javaid & Haleem, 2019). The adoption of specialized medical implants or models as per the needs of individual patients has been made possible due to the popularization of Industry 4.0 technologies (Ghobakhloo, 2018).

Many startups have come up with unique solutions during Covid times, either to quickly identify infected individuals with whom they have come in contact, in identifying those who are not wearing a mask, or in developing COBOTS in quarantine centers for remote monitor these patients (Seidita *et al.,* 2021). The tremendous resilience displayed by India's IT industry during the pandemic, particularly in the healthcare sector, was praiseworthy. As scientists raced against time to vaccinate the vulnerable population and to find a cure for the pandemic, technologists too, have jumped in to find solutions, helping in testing, tracing, and providing treatment (Seidita *et al.,* 2021). The RPM devices that could record and transmit patient biometrics, vital signs, and disease-related data to healthcare providers saw substantial growth, during this period (Hathaliya *et al.,* 2019). The market for RPM devices is expected to reach $1.7 billion globally by 2027, indicating significant growth potential for this field of study. This study, therefore, tries to evaluate the extent and usage of Artificial Intelligence in the healthcare sector.

The remaining paper is organized into five sections. Section 2 investigates the usage of Artificial Intelligence in healthcare. This was demonstrated by analyzing the usage of AI in various sectors using Google Trends. Further sub-sections focused on the application of AI in healthcare and remote patient monitoring devices based on AI. Section 3 studies the application of remote monitoring devices during the Covid times using a case study method. Section 4 analyses the observations and challenges faced in their usage. The conclusion and directions for future AI research were presented in Section 5.

2. Literature Review

AI is defined as the ability of digital computers capable of performing tasks intelligently without being explicitly instructed. The application of Artificial Intelligence has increased exponentially to solve complex problems in various business applications, scientific studies, and other societal issues. AI can explore through a vast knowledge base, process data, and develop innovative solutions, to enable precise data-driven decisions and modelling tools (Lee *et al.,* 2018). AI and other related technologies are transforming the industrial paradigm, showing the indispensable role of Industry 4.0. technologies in various sectors (Rong *et al.,* 2020).

2.1 Comparative Search Analysis using Google Trends

To understand the popularity of AI and its applicability in various fields, a global search of comparative analysis has been done in Google Trends. The Google Trends search was performed to find user interests in the usage of AI across a variety of industries, including finance, education, agriculture, and healthcare, in the past 20 years.

Google Trends can be used to compare search volumes of keywords and identify event-triggered spikes. Google Trends data can be extremely beneficial to marketers (Wordstream.com, n.d.) to know the latest market trends.

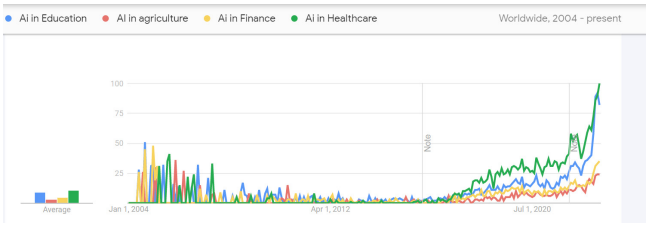

Figure 1. Google Trends for AI in various sectors from 2004-2023

Figure 1 clearly shows how the global search for "AI in Healthcare" has spiked during Covid times showing the popularity of the application. Analysis shows how technology is benefitting the healthcare industry. Various medical specializations are using AI such as oncology, cardiology, neurology etc., to increase day-to-day operating performance in healthcare organizations, which can enhance and improve healthcare delivery (Spatharou *et al.,* 2020). This shows the rising importance of AI, and by 2025 the global market is expected to be about $60 billion due to the severe shortage of healthcare professionals (Spatharou *et al.,* 2020).

2.2 Application of Artificial Intelligence (AI) in Healthcare

Artificial Intelligence (AI) is a collection of technologies like Machine Learning (ML), Neural Networks, Deep Learning, etc. contributing significantly to addressing challenges and revolutionizing the healthcare sector. AI can detect abnormalities in a data set and is employed across various clinical scenarios, to diagnose, treat, and predict outcomes. Sommer (2015) stressed that Industry 4.0 technologies provide a roadmap for the development of personalized devices. Hazarika (2020) pointed out that AI is being used to track patient clinical results and has evolved as a powerful platform for developing diagnostic tests and vaccine development (Sohrabi *et al.,* 2020). AI is increasingly being used to scan automatically and gather data from clinical records for quality reporting (Nundy & Hodgkins, 2018).

Computer techniques are most commonly used in medical Artificial Intelligence (mAI) to conduct clinical diagnoses and recommend treatments (Davenport & Kalakota, 2019). According to Sarker (2021), machine learning is one of the popular forms of AI; which uses statistical methods to train models using data and then 'test' by fitting them in the data. ML algorithms are capable of performing specific tasks by recognizing precise relationships in the data. Common ML algorithms of data mining used in healthcare applications (Davenport & Kalakota, 2019) are decision trees, neural networks, Support Vector Machine (SVM), k-means, Logistic Regression, Naïve Bayes classifier, and various hybrid algorithms (Jackins *et al.,* 2020), used for the prediction of heart disease, breast cancer prediction, diabetes risk (Wu *et al.*, 2022), pneumonia (Caruana *et al.,* 2015), etc. Deep learning models are a subset of ML consisting of an input layer, an output layer, and many hidden layers. The majority of machine learning and precision medicine applications require huge datasets to train and test the outcome variable. Poor data quality leads to poor AI results.

2.3 Application of Remote Patient Monitoring Devices in Healthcare

Invasive methods are used in traditional patient monitoring, which necessitates skin contact to assess health parameters (Malasinghe *et al*., 2019). The healthcare sector has been disrupted by technological developments in data transmission by the availability of noninvasive technologies that do not require touching patients' bodies to continuously check their vital signs. (Malasinghe *et al.,* 2019). The ability to monitor patients remotely, outside of a medical setting, with the use of technology, and in real-time, has significantly increased in recent years (Taylor *et al.,* 2019). Radar-based and image-based approaches are the two main kinds of contactless Remote Patient Monitoring applications (RPM). Radio frequencies are used by radar-based devices to acquire data inputs for their systems. While, image-based systems analyze photographs of patients and detect illnesses depending on the trained data sets (Malasinghe *et al.,* 2019).

RPM systems can be found in blood pressure monitors, heart rate monitors (ECG), brain monitoring (EEG), respiratory rate monitors, temperature monitors, vital sign monitors, etc. (Khan & Alotaibi, 2020; Bhattacharya *et al.,* 2021). RPM technologies enable tracking real-time changes in a patient's vital signs and symptoms, thereby aiding in freeing up beds and bringing down expenses, which have transformed healthcare monitoring applications (Bhattacharya *et al.,* 2021). The Remote patient monitoring devices are linked to wireless networks such as Wi-Fi, a cellular connection, and Bluetooth, which allows them to send patient data directly to the appropriate monitoring agency or a healthcare provider (Bhattacharya *et al.,* 2021).

2.4 Application of AI-Enabled Remote Patient Monitoring Devices in Healthcare

Artificial Intelligence (AI) has the potential to revolutionize clinical judgments in various healthcare domains (Bai *et al.,* 2018; Seetharam *et al*., 2019); like in cancer research (Forsyth *et al*., 2018); for diabetes detection (Kavakiotis *et al.,* 2017); in cardiology (Weng *et al.,* 2017), to remotely monitor Alzheimer's patients (Casacci *et al.,* 2015), etc. Javaid and Haleem (2019), highlighted that smart technologies are providing exact information to the doctor about the patient-specific requirements, before surgery. Reinforcement learning is used by AI-enabled RPM architectures to learn human behaviour patterns to track the specific health parameters of each patient and identify any early signs of health decline (Shaik *et al.,* 2023). AI and machine learning algorithms are being combined with the sensor data from the wearables to get updated real-time data throughout the monitoring period, and enable patient management (Bai *et al.,* 2018). This allows for constant observation of the patients outside of clinical settings. While using RPMs, huge amounts of data are generated from each patient using IoT devices. Data processing includes a processing unit and a storage unit, for data receiving and transmitting (Malasinghe *et al.,* 2019), and stored in the cloud. The data so collected is shared with concerned parties to monitor trends. This improves the patient's quality of life significantly (Khan & Alotaibi, 2020).

AI-ML was used extensively to develop new devices to perform a variety of tasks during the Covid era. Using mobile location, facial recognition, and other methods, they were able to trace the infected, identify the infected areas, manage healthcare-related emergencies, automatic bed allocation, recommend nearby hospitals and vaccine centers, etc. This helped to stop the virus from spreading (Goswami & Sebastian, 2022). According to Johns Hopkins Medicine Corona Facility Center (2020) emergency rooms in hospitals were able to isolate patients during the COVID-19 period and ensure the safety of nursing staff, thereby lowering the risk of patient exposure, and reducing the workload on medical professionals (Semigran *et al.,* 2016). The most recent COVID-19 has increased the usage of patient monitoring systems, with a significant number of patients communicating with their doctors from home.

To understand the usage of AI & ML-enabled remote patient monitoring devices, two AI-powered RPM devices were taken, one radar-based, and another image-based, for case study analysis. The data collected was secondary.

3. Methodology

India's First "Contactless Remote Health Monitoring device" Dozee (Dozee.Ai, 2023) was devised to monitor patients continuously, without the need for any physical contact from medical practitioners. The device uses 'AI-powered Advanced Health Intelligence (AHI)' and 'Early Warning Systems (EWS)' by providing alert signals and reporting early health deterioration for rapid medical intervention. Dozee makes use of Ballisto Cardiography (BCG) technology (Ahmed *et al.,* 2022), where a tiny sensor sheet is positioned beneath the user's mattress to collect data on the patient's body's micro-vibrations. The device monitors important health parameters like heart rate, breathing rate, sleep quality, stress and recovery levels, and sleep apnoea index, using non-intrusive contactless technology. This eliminates the need for nurses to visit patients and take readings. Dozee has kept track of Covid patients who were quarantined, to detect health problems early. This has aided in protecting nurses

and other healthcare professionals from infection and also lessened the need for personal protective equipment and sanitisers. Dozee's technology is patented and made in India and is clinically proven to be 98.4% accurate. The company has also launched an AI-powered electrocardiogram (ECG) patch to monitor patients with cardiovascular disease and to identify early signs of cardiac deterioration thereby ensuring timely medical intervention (Dozee.ai, 2023).

Another indigenous healthcare start-up, Qure.ai, (2021), quickly interprets radiology scans by recognizing and interpreting chest X-rays, keeping track of ICU patients, and monitoring their pulmonary conditions. The qXR algorithm of Qure.ai employs a variety of deep learning models to identify typical lung irregularities and covid-induced pneumonia symptoms like opaque patches and thick areas on the sidewalls of the lungs. Their technology generates chest X-ray interpretation reports faster and more accurately than people, aiding in the detection of COVID-19, tuberculosis, chronic obstructive pulmonary disease, lung cancer, and medical emergencies. Through the evaluation of the Radiographic Assessment of Lung Edema (RALE) score, AI-based algorithms can accurately diagnose the severity of lung deterioration and distinguish between mild and severe pneumonia, making a distinction between covid and non-covid patients with 95% accuracy, thereby saving precious time and lives. The automated medical imaging tools from Qure.ai allow doctors to quickly identify crucial situations and diagnose medical conditions, preventing fatalities and enhancing patient care.

4. Observations

Remote monitoring focuses on patients with chronic diseases, post-surgery home monitoring for patients, senior citizens, and patients from rural areas with limited access to healthcare facilities, resulting in increased global demand in the coming years (Hozhabri *et al.,* 2020). With the introduction of remote health monitoring applications, elderly patients can now do their daily lives without the assistance of a caretaker. This enables patients to perform routine tests using a handheld medical device and submit these results to a doctor in real-time without having to travel to a testing center. This has made it possible to reduce prolonged hospitalizations and the economic burden on their families. Many research studies show that by identifying patterns, physicians can diagnose anomalies and abnormalities, undetected by the human eye, to avoid expensive treatments, thereby proving helpful for the patients. This is aiding in the detection of illnesses in real time, as well as the prevention of disease progression and premature death.

4.1 Challenges in RPM Devices

There are some pressing challenges concerning data storage, data encryption, data integrity, data protection, and security breaches using RPM devices. Small healthcare organizations and rural hospitals are encountering barriers due to poor internet accessibility for effective RPM implementation. Modern technology like cell phones may be difficult for elderly persons to possess and utilize. There is a huge knowledge gap among the data developers as they are not clinical professionals, leading to anomalies in the data. The demand for huge datasets compels developers to acquire data from a large number of patients, which causes infringement of their confidentiality, and unethical data sharing, between health institutes and AI companies. Unless AI algorithms are trained to differentiate between benign abnormalities and clinically significant lesions, there are chances of false positives. The further challenge posed by AI is reducing the need for human interaction. Instead of working as a complement, or working as a substitute, AI is threatening to displace doctors and other nursing workers from their jobs, leading to greater unemployment.

5. Conclusion and Scope for Future Research

The present study covers a lot on the usage of advanced technologies in revolutionizing the healthcare sector. Both the remote monitoring devices taken up for the study have done a tremendous job in aiding covid positive patients. This has significantly reduced in spreading of the virus and in assisting doctors to track the deterioration of the patient's health parameters, in real-time, resulting in reduced costs

and hospitalizations. The usage of smart technologies has made the healthcare sector more predictive and preventive, increasing the efficacy, analysis, and treatment outcomes. The research on the usage of AI and ML in the healthcare sector has increased substantially in recent times, creating an impact on society. Remote monitoring devices are aimed at the rapidly growing elderly population, neonates, post-surgery patients, patients with chronic illnesses, mobility conditions, and other disabilities. The primary challenges faced are connectivity issues, reliability and accuracy of data collected, difficulties in using these devices, and investment costs. Huge data is generated, which leads to storage costs and skills to analyze this data.

Artificial Intelligence in healthcare can support faster delivery of care, accelerate the diagnosis time, and manage the health of bulging populations, more proactively and dynamically. This is providing better time management to the doctors and nursing care to focus more on critical patients. It is crucial to emphasize that AI applications will not replace human clinicians but rather will enable them to focus more on crucial human-related tasks and make accurate diagnoses promptly. The global demand for analytics and AI skills is increasing, affecting the future of every sector as companies are expanding their use of digital technologies. The next trend in RPM technology is miniaturization, where device manufacturers are reducing the size of the devices, and making them less invasive. As the world shifts toward contactless methods, newer technologies must be developed for the betterment of mankind. As AI is set to transform every industry, it is very essential to understand how to create new products to increase the value of the company or improve the existing products.

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