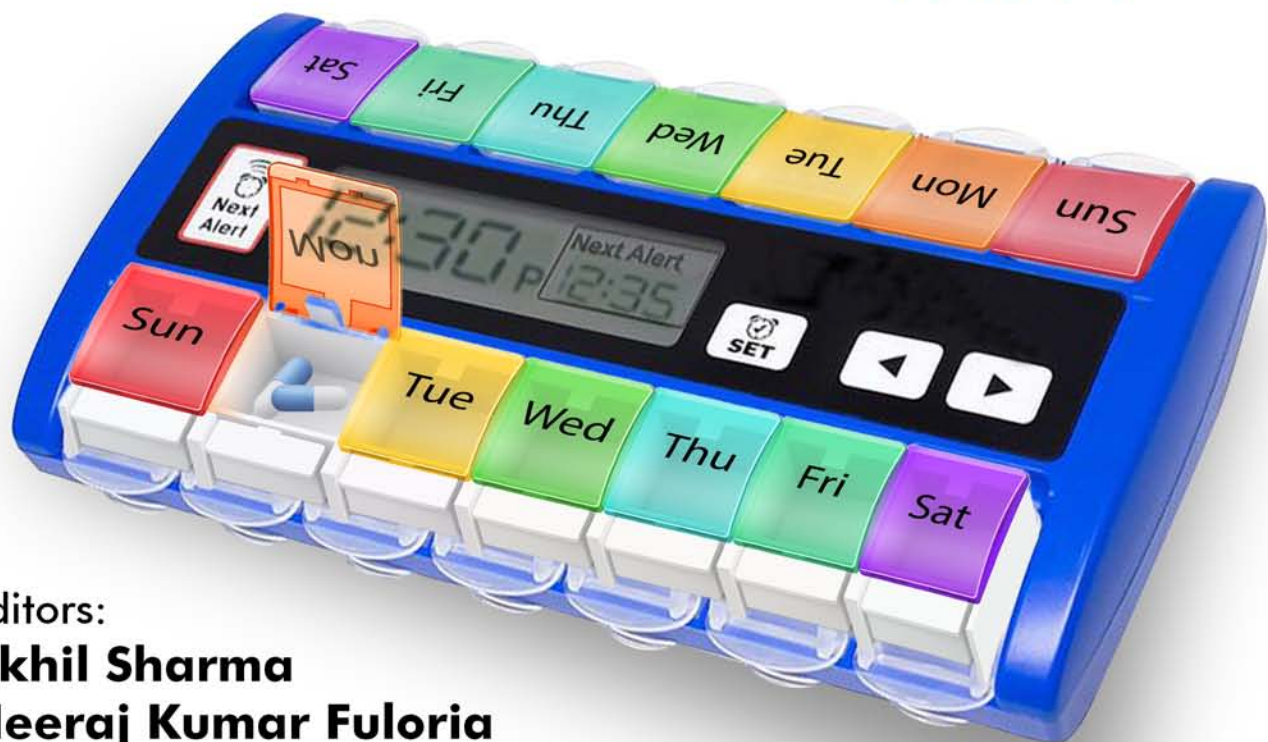


THE DIGITAL PILLBOX

INTEGRATING AI, IOT, AND PHARMA SOLUTIONS

PART 1



Editors:

Akhil Sharma

Neeraj Kumar Fuloria

Pankaj Kumar Singh

Shaweta Sharma



Bentham Books

The Digital Pillbox: Integrating AI, IoT, and Pharma Solutions

(Part 1)

Edited by

Akhil Sharma

*R.J. College of Pharmacy
Raipur, Gharbara, Tappal, Khair
Uttar Pradesh, India*

Neeraj Kumar Fuloria

*Department of Pharmaceutical Chemistry, Faculty of
Pharmacy, AIMST University
Semeling Campus
Bedong, Kedah, Malaysia*

Pankaj Kumar Singh

*Institute of Biomedicine, University of Turku
Turku, Finland*

&

Shaweta Sharma

*School of Medical and Allied Sciences
Galgotias University
Greater Noida, Uttar Pradesh
India*

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Editors: Akhil Sharma, Neeraj Kumar Fuloria, Pankaj Kumar Singh & Shaweta Sharma

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FOREWORD

The healthcare sector stands at the cusp of a profound transformation. With the rapid advancement of digital technologies, traditional models of care are evolving into interconnected ecosystems that prioritize precision, efficiency, and patient empowerment. Among the most impactful developments in this journey is the fusion of Artificial Intelligence (AI), the Internet of Things (IoT), and pharmaceutical innovation, a convergence that holds immense promise for tackling longstanding challenges in medication management and beyond.

The Digital Pillbox: Integrating AI, IoT, and Pharma Solutions (Part 1) delves into this very intersection, offering a timely and insightful exploration of how these cutting-edge technologies are reimagining healthcare delivery. From addressing the persistent issue of medication non-adherence to enabling real-time tracking and personalized treatment plans, this volume presents both the urgency and the opportunity inherent in this digital transformation.

What sets this work apart is its holistic approach combining theoretical insights with real-world applications to illuminate how AI and IoT are not just tools, but enablers of a more responsive, data-driven, and patient-centric care model. The emphasis on smart pillboxes, remote monitoring, and predictive analytics is particularly noteworthy, showcasing how integrated digital solutions can improve clinical outcomes while enhancing the daily lives of patients.

This book is the result of a collaborative effort by forward-thinking researchers and professionals who recognize the necessity of embracing innovation to drive sustainable healthcare improvements. It offers a roadmap for clinicians, pharmacists, technologists, policymakers, and other stakeholders who are navigating the digital health frontier.

As we move forward into an era of smarter medicine, the Digital Pillbox stands as both a guide and a call to action inviting us to rethink, retool, and revolutionize the way we approach care in the 21st century.

Shelly Pathania
Senior Researcher
Institute of Biomedicine
University of Turku
Turku, Finland

PREFACE

In today's dynamic healthcare landscape, the convergence of Artificial Intelligence (AI), the Internet of Things (IoT), and pharmaceutical innovation marks a pivotal transformation. The Digital Pillbox: Integrating AI, IoT, and Pharma Solutions (Part 1) explores this evolution, focusing on how these technologies are reshaping medication adherence, personalized medicine, and healthcare delivery.

This volume begins by addressing the root challenges of medication non-adherence, followed by an in-depth analysis of AI's role in tailoring treatments and enhancing pharmaceutical care. It highlights how IoT-enabled solutions like smart pillboxes and remote monitoring are empowering both patients and providers. Through chapters dedicated to real-time tracking, predictive analytics, and smart integration, the book outlines a forward-thinking framework for improving outcomes and optimizing therapy.

This work is a collaborative effort by dedicated researchers and professionals, aiming to guide healthcare stakeholders in embracing this digital revolution to foster smarter, more connected, and patient-centric care systems.

Akhil Sharma

R.J. College of Pharmacy
Raipur, Gharbara, Tappal, Khair
Uttar Pradesh, India

Neeraj Kumar Fuloria

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, AIMST University
Semeling Campus
Bedong, Kedah, Malaysia

Pankaj Kumar Singh

Institute of Biomedicine, University of Turku
Turku, Finland

Shaweta Sharma

School of Medical and Allied Sciences
Galgotias University
Greater Noida, Uttar Pradesh
India

List of Contributors

Akanksha Sharma	R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India
Akhil Sharma	R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India
Ashish Verma	Mangalmay Pharmacy College, Greater Noida, Uttar Pradesh, India
B. Rama Mohana Reddy	Department of Civil Engineering, Aditya University, Surampalem, India
B. Rama Sagar	Department of Civil Engineering, Aditya University, Surampalem, India
Dimple Singh Tomar	Kharvel Subharti College of Pharmacy, Swami Vivekanand Subharti University, Meerut, India
Gaddam Dinesh	Department of Civil Engineering, Aditya University, Surampalem, India
K.K. Yashwanth	Department of Civil Engineering, Aditya University, Surampalem, India
Neeraj Kumar Fuloria	Department of Pharmaceutical Chemistry, Faculty of Pharmacy, AIMST University Semeling Campus, Bedong, Kedah Darul Aman, Malaysia
N. Bhaskara Rao	Department of Civil Engineering, Aditya University, Surampalem, India
P. Lakshmi	Department of Civil Engineering, Aditya University, Surampalem, India
P. Siva Kumar	Department of Civil Engineering Aditya University, Surampalem, India
P. Ravi Kishore	Department of Civil Engineering, Aditya University, Surampalem, India
Shaweta Sharma	School of Medical and Allied Sciences, Galgotias University, Greater Noida, Uttar Pradesh, India
Sunita	Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India
Shekhar Singh	Faculty of Pharmacy, Babu Banarasi Das Northern India Institute of Technology, Lucknow, Uttar Pradesh, India
S. Govindarajan	Department of Civil Engineering, Aditya University, Surampalem, India
Sumit Chowdary Mukund	Department of Civil Engineering, Aditya University, Surampalem, India
S. Ananda Kumar	Department of Civil Engineering, Aditya University, Surampalem, India
Shivkanya Fuloria	Department of Pharmaceutical Chemistry, Faculty of Pharmacy, AIMST University Semeling Campus, Bedong, Kedah, Malaysia

CHAPTER 1

Understanding Medication Adherence Challenges

Akanksha Sharma¹, Shaweta Sharma², Sunita³, P. Lakshmi⁴ and Akhil Sharma^{1,*}

¹ *R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India*

² *School of Medical and Allied Sciences, Galgotias University, Greater Noida, Uttar Pradesh, India*

³ *Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India*

⁴ *Department of Civil Engineering, Aditya University, Surampalem, India*

Abstract: Despite its relevance in managing different health conditions, medication adherence remains difficult for diverse reasons. This abstract details the complicated nature of medication adherence difficulties, which involve patient-related factors and healthcare system complexities, as well as specific issues related to medications. For medical practitioners seeking to make outcomes better for their patients, it is important to know how these three factors interact with each other. These factors include socioeconomic status, illness literacy, and psychological obstacles. Socio-economic barriers such as financial incapability and lack of insurance often affect the capability of patients to adhere to given prescriptions. Lack of awareness about certain drugs leads to confusion about recommended treatment, while depression and anxiety are examples of some psychological aspects that increase non-adherence. Communication breakdowns in the healthcare system, prescription complexity, and limited access to care have become problematic within the field today. Inadequate communication between patient-provider relationships and lack of clarity in drug instructions lead to misunderstanding or non-compliance. That aside, a range of complex prescription processes combined with accessibility barriers increase these challenges, predominantly among those individuals who are at higher risk due to social exclusion. Additionally, whether due to side effects observed or perceived, efficacy declines regimen complications and further complicates adherence efforts. Patients can stop taking their medications because they cannot stand the side effects experienced; they may also find it difficult to follow complex dosing schedules or lose interest if they do not see any improvement after all. Whereas family dynamics may be responsible for this behavior in some instances, cultural beliefs coupled with social networks influence patients' attitudes toward medication continuity. The culture-sensitive healthcare environment promotes adherence, while stigma and cultural barriers undermine the process. In brief, handling medication non-compliance takes into account the interconnectedness among patients' characteristics of healthcare systems, medicines, and environmental features. This way, healthcare providers enhance their patients' ability to

* **Corresponding author Akhil Sharma:** R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

take drugs in the long term and ensure that equitable distribution is upheld by addressing such hindrances.

Keywords: Anxiety, Adherence, Depression, Health, Medication, Non-adherence, Patient, Psychology, Regimens, Record, Socioeconomic, Technology, Treatment.

INTRODUCTION

Medication adherence is an important pillar of effective healthcare management that encompasses the level to which patients stick to their prescribed drug plans. It is a crucial institution in terms of ensuring that individuals get all the curative benefits contained in their presumed medication scripts. Nevertheless, even with its undeniable relevance, medical non-adherence remains a widespread and complicated matter globally, leading to many hardships for healthcare systems as well as individual patients [1].

In recent years, healthcare specialists, policymakers, and scholars have paid increasing attention to medication non-adherence as a serious issue. The profoundness of its effects justifies this increased level of consciousness. Nonadherence is thus closely linked with a range of negative health effects, including disease advancement, morbidity, and mortality rates, and high healthcare costs. Besides, it weakens interventions for different medical conditions, from chronic diseases like diabetes and hypertension to acute illness and mental health conditions [2].

The multifaceted nature of the challenges linked to adherence means that understanding such problems would require a deeper knowledge of what causes non-adherence. These factors cover a wide range, including those related to patients, pharmaceutical and health services systems, and socio-environmental ones. For instance, patients' socioeconomic status, health literacy, and psychological barriers like depression and anxiety can have great impacts on their medication-taking behaviors. Moreover, healthcare systems are complex, with communication breakdowns and limited access to care, which further worsen adherence issues, especially among vulnerable populations [3, 4].

In addition, medication-specific aspects such as adverse effects, treatment burden, and perceived effectiveness can be highly influential in determining the behavior of patients when following prescriptions. In this regard, patients may stop using their drugs due to adverse reactions that have become unbearable or find it difficult to stick to a complex dosage regimen, thus compromising therapeutic outcomes. Additionally, socio-environmental factors like family dynamics, social support systems, and cultural beliefs are key determinants of adherence to

medication, necessitating tailored approaches aimed at addressing these contextual factors [5].

Medication adherence is one challenge that seems unbeatable. However, things are not entirely hopeless. Medical practitioners have the necessary tools and expertise to develop targeted interventions that boost medication adherence, thereby leading to better patient outcomes. Ideally, it is multidisciplinary and incorporates evidence-based strategies derived from various fields such as medicine, psychology, and public health. With technologies like mobile health applications and telemedicine platforms in place, health providers can improve patient involvement and also monitor their medication adherence through them [6].

Moreover, it is through encouraging patient-centered care approaches that prioritize shared decision-making and customized treatment plans that patients will be equipped to be actively involved in their healthcare journey. Equally important is building effective communication between patients and the health providers as well as intervening for a better understanding of health literacy, which often leads to misunderstandings relating to drugs, hence a partnership aimed at treating patients. Besides, dealing with structural impediments such as the availability of affordable medicines and healthcare facilities is crucial in ensuring there is equal access as well as reducing gaps in medication adherence [7].

PATIENT-RELATED FACTORS

Patient-related factors for medication adherence are summarized in Fig. (1).

Socioeconomic Status

Financial Constraints

Among people with low socioeconomic status, financial constraints are a major issue when it comes to taking medicine as directed. Patients' capacity to follow their prescribed treatments closely is dependent on their ability to pay for the drugs themselves, which has an effect on health results and general welfare. Among individuals who do not have much money, high prices of medications can make them fail to take them regularly. Many chronic diseases need continuous treatment, hence the higher expenses in the long run with regard to these drugs. Inadequate earnings may hinder patients' ability to buy prescription medicines; lack of insurance coverage or expensive co-payments could force individuals into

CHAPTER 2

AI's Role in Personalized Medication Management

Sunita¹, Akhil Sharma², Akanksha Sharma², P. Siva Kumar³ and Shaweta Sharma^{4,*}

¹ Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India

² R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

³ Department of Civil Engineering Aditya University, Surampalem, India

⁴ School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

Abstract: Healthcare has gone through a paradigm change, specifically in personalized medicine, due to the development of Artificial Intelligence (AI) technology. This chapter will discuss how AI is transforming healthcare delivery in general, particularly through precision medicine. Such AI technologies such as machine learning, deep learning, natural language processing, predictive analytics, robotics, and automation can utilize extensive databases that include patient genomics, medical history and real-time health monitoring, as well as patient demographics. By using AI to integrate data from Electronic Health records along with other patient sources, genomic data, and wearable IoT devices, it provides a holistic profiling of patients to predict their responses to drugs and identify possible adverse effects. Besides, AI also fast tracks drug discovery and development by target identification to drug repurposing, reducing time frames for research and development. Advances in Clinical Decision Support Systems (CDSS) enhance the decision-making process, providing real-time insights that guide healthcare professionals. However, the implementation of AI in personalized medicine comes with its own set of challenges. However, there are ethical issues associated with data privacy, biases in AI algorithms, regulatory considerations, and more. When it comes to the adoption of AI, the integration with existing infrastructure, training, and educating health professionals become key elements. There is a lot of potential for the future, as technology is constantly advancing and is sure to remove barriers preventing us from a more efficient, patient-centered, healthcare model.

Keywords: Artificial intelligence, Adverse drug reaction, Clinical decision support systems, Drug discovery, Drug development, Electronic health records, Genomics, Healthcare, Internet of things, Medication, Management, Precision medicine, Personalized, Prediction, Repurposing, Wearables.

* **Corresponding author Shaweta Sharma:** School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India;
E-mail: shawetasharma@galgotiasuniversity.edu.in

INTRODUCTION

Precision medicine, also called personalized medicine or individualized medicine, is a healing technique that acknowledges the dissimilarity among persons and aims at adjusting medical care and interventions to suit individual peculiarities. In contrast to the customary “one-size-fits-all” approach to health care that depends on standardized protocols and therapies, precision medicine considers different genetic, environmental as well as lifestyle factors associated with an individual’s health and disease propensity [1].

The basic idea behind precision medicine is the use of genomics, molecular biology, data science, and related technologies to understand the molecular basis of diseases and develop personal treatment options. The field has grown and changed significantly during the past years due to fast developments in genomic sequencing technology, bioinformatics tools, and computational analytics [2].

One of the major principles of precision medicine embraces genomic data for diagnosis, treatment selection, and therapeutic decision-making. Researchers and medical practitioners analyze the patient’s genetic makeup using genome sequencing in order to find out genetic variations that are associated with specific diseases or drug responses among mutations and biomarkers. By understanding the genetic basis of ailments, doctors can produce individualized curatives that suit each patient's genetic blueprint [3].

Precision medicine is more than genomics. It also involves a range of other omics technologies, such as transcriptomics, proteomics, and metabolomics, that shed light on the molecular pathways and mechanisms of diseases. By combining data from various omics platforms, scientists can obtain a more comprehensive understanding of how diseases develop and even discover new drug targets [4].

Precision medicine is not confined to molecular data only; it also includes other sources of information such as Electronic Health Records (EHRs), imaging studies, and patient-reported outcomes. By integrating different datasets, healthcare providers can have a holistic view of each patient's health status and develop appropriate treatment plans [5].

The main objective of precision medicine is to go beyond a reactive, one-size-fits-all approach to healthcare and towards a more proactive and preventive model. Precision medicine enables early detection, risk stratification, and implementation of preventive interventions by identifying high-risk individuals for some diseases based on their genetic predisposition, lifestyle choices, and exposures to environmental elements [6].

Precision medicine also involves pharmacogenomics, which uses genetic information to predict how a person reacts to drugs. By determining gene variants that alter drug metabolism, efficacy, or toxicity, doctors can choose the right medication and dosage for optimum therapy results and reduced side effects [7].

Evolution and Importance

Table 1 summarizes the evolutionary milestones and the significance of precision medicine in transforming healthcare delivery and improving patient outcomes.

Table 1. The evolution and importance of precision medicine.

Evolution	Importance
Emergence of Genomic Technologies	- The emergence of genomic sequencing technologies, such as Next-Generation Sequencing (NGS), has made it possible to examine genetic information quickly and inexpensively. - Facilitates identification of genetic variants, mutations, and biomarkers linked to diseases, leading to personalized treatment decisions [8].
Advancements in Omics Technologies	- Integrating the use of transcriptomics, proteomics, metabolomics, and other 'omics' data for a more comprehensive understanding of disease mechanisms and pathways. - Provides a holistic understanding of the molecular signatures underlying diseases, helping in the identification of novel therapeutic targets [9].
Integration of Electronic Health Records	- EHRs are used to capture clinical data, imaging studies, and patient-reported outcomes to develop a complete patient profile. - Enables healthcare providers to create personalized treatment plans for each patient based on a holistic view of health status and medical history [10].
Advancements in Pharmacogenomics	- Develop pharmacogenomics testing that provides personalized prescription and dosage guidance by utilizing genomic information on drug efficacy and metabolism. Optimizes medication selection, dosing, and management to increase therapeutic results and decrease side effects [11].
Shift towards Preventive and Predictive Medicine	It is important to focus on early detection, risk stratification, and prevention strategies based on an individual's genetic predisposition, environmental exposure, and lifestyle. - Enables proactive disease management, decreases disease burden, and improves long-term health outcomes [12].
Ethical, Legal, and Social Implications	- Recognition of ethical considerations about privacy, informed consent, genetic discrimination, and equity in access to genomic technologies. - Ensures responsible and equitable implementation of precision medicine, safeguarding individual rights, autonomy, and privacy [13].

CHAPTER 3

IoT Integration: Tracking Medication Intake

Shekhar Singh¹, Akhil Sharma², Sunita³, P. Ravi Kishore⁴ and Shaweta Sharma^{5,*}

¹ Faculty of Pharmacy, Babu Banarasi Das Northern India Institute of Technology, Lucknow, Uttar Pradesh, India

² R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

³ Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India

⁴ Department of Civil Engineering, Aditya University, Surampalem, India

⁵ School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

Abstract: Non-adherence occurs when patients do not take their medications as prescribed. This is a major challenge in healthcare that has detrimental consequences on the health outcomes of patients and health systems. An emerging solution to this problem has been identified by using Internet of Things (IoT) capabilities. This chapter investigates the use of IoT for medication intake tracking, giving a detailed account of its advantages, mechanisms, limitations, and prospects. The IoT's role in healthcare and medication non-adherence are examined at the beginning of the discussion. The chapter explores various IoT solutions for medication management, including smart pill boxes, wearables, and apps, their functions, and real-time monitoring abilities. The chapter highlights the key benefits of integrating IoT into healthcare for patients and care providers, such as better compliance rates, greater patient involvement, and the availability of immediate adherence data to enhance decision-making. Additionally, the chapter examines the practicality of IoT in medication tracking by looking at how it works technically and how sensors, connectivity, and data analytics are used to collect and analyze adherence data. Also, privacy concerns, as well as integration with existing healthcare systems, are some of the possible challenges that are discussed. The chapter also outlines forthcoming trends such as an improvement in IoT technology, possibilities for AI and machine learning incorporation within it, and a wider use of IoT solutions in other healthcare sectors. This chapter takes insights from different fields to give an all-inclusive understanding of how IoT integration can disrupt medication management, leading to better patient outcomes and healthcare delivery.

* **Corresponding author Shaweta Sharma:** School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India; E-mail: shawetasharma@galgotiasuniversity.edu.in

Keywords: Adherence, Data analytics, Health, Healthcare, Internet of things, Medication, Mobile applications, Non-adherence, Patient, Real-time, Sensors, Smart pill dispensers, Wearable devices.

INTRODUCTION

Adhering to prescribed medication is a major problem in health care, comprising many complex difficulties that highly affect the health of patients and the efficiency of healthcare systems in general. One of the main challenges in this case is the intricacy associated with prescription regimens, whereby patients have to deal with multiple drugs, each having different doses, timing, and administration requirements. The complicated balancing involved can be too much for patients, resulting in perplexity, mistakes, and finally noncompliance with prescribed schedules [1].

Furthermore, forgetfulness is a common problem, with patients finding it hard to stick to their medication schedules because of momentary memory lapses or inability to sustain regular routines in the middle of day-to-day commitments. Financial obstacles also make the situation worse by imposing a huge financial burden on patients because of the high cost of prescription drugs, thereby forcing them to choose between life-saving drugs and food, shelter, and other basic requirements. Additionally, there is looming dread about possible side effects or any other unwanted reactions that stop individuals from adhering to what has been prescribed for the fear of their own lives and health [2].

Furthermore, adherence difficulties are worsened by inadequate health literacy since patients without enough knowledge of how to take medicines or doses can mistakenly move away from their prescriptions, bringing ineffective treatment results or effects on them. Another thing that hampers adherence attempts is social factors such as stigma towards some medical conditions or lack of support system; in this regard, patients may feel guilty and be unwilling to express themselves through discussing openly their medication use and asking for help with their treatment [3].

The importance of medication adherence for achieving positive health outcomes must be emphasized in this labyrinthine landscape of challenges. As the cornerstone to effective disease management and control, adhering to prescribed medications is especially critical in cases of chronic illnesses such as diabetes, hypertension, and HIV/AIDS. For instance, optimal adherence can enable patients to achieve and maintain optimum disease control, which reduces the risk of disease exacerbation and complications while enhancing overall well-being [4].

When patients follow their recommended medication plan, they can cut down considerably on the probability of hospitalizations or ER visits, easing pressure from healthcare providers and reducing health care costs. More so, constant adherence is vital in blocking diseases from spreading further, enabling individuals to maintain their capability status, improve their life standards, and reduce the long-term effects of untreated or inadequately treated cases. From an economic perspective, adherence to medications leads to significant savings through a reduction in healthcare utilization, prevention of expensive complications, and a decrease in the need for costly medical interventions or procedures [5].

At the population level, public health implications of adherence improvement are extensive and include disease prevention, mitigation of healthcare disparities, and community health promotion and well-being. Consequently, addressing the multiple challenges around medication adherence is essential in order to achieve optimal health outcomes, enhance patient care, and ensure the viability of healthcare delivery systems. By using individualized procedures, inventing new technologies, and encouraging interaction among healthcare givers, policymakers, and other parties concerned, we can attempt to overcome these hurdles and support the use of drugs as an important building block in health service provision. The importance of medication adherence for health outcomes is shown in Fig. (1) [6, 7].



Fig. (1). Importance of medication adherence for health outcomes.

CHAPTER 4

Remote Patient Monitoring: A Paradigm Shift

Dimple Singh Tomar¹, Shaweta Sharma², Akanksha Sharma³, Gaddam Dinesh⁴ and Akhil Sharma^{3,*}

¹ Kharvel Subharti College of Pharmacy, Swami Vivekanand Subharti University, Meerut, India

² School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

³ R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

⁴ Department of Civil Engineering, Aditya University, Surampalem, India

Abstract: Revolutionizing the healthcare delivery process, Remote Patient Monitoring (RPM) alters the traditional way of communication between care providers and patients. It delves into the multifaceted effect of RPM that relates to its changing position in the healthcare environment. This also means that with technological advancements, like wearable techs, integrating other devices under IoT, and using AI technologies, RPM allows for healthcare parameters' tracking outside normal clinical settings. Consequently, this transition towards proactive data-enabled medical practice provides patients with a chance to take part in their treatment as well as offering doctors immediate information for making decisions. In this chapter, we explore the use of Remote Patient Monitoring (RPM) in different healthcare areas, such as long-term condition care, senior care, and post-surgery recovery, to demonstrate its capacity to enhance patients' results, cut down on health expenses, and improve the quality of care. The paper also highlights legal policies that govern RPM's implementation, putting a lot of emphasis on privacy issues, security measures, and adherence to healthcare legislation. Furthermore, it addresses ethical considerations, including patient consent, ownership of data, and fairness in reaching information. We seek for the future in aspects like predictive analytics, personalized medicine, and global expansion of RPM initiatives. But despite all these encouraging possibilities that RPM holds, there are still some challenges that must be overcome, such as lack of interoperability, reimbursement difficulties, and differences in digital health literacy. This abstract concludes by highlighting the transformative capabilities of RPM in reforming healthcare landscapes toward a more connected patient-centric model of care delivery. By promoting teamwork between stakeholders and addressing barriers that exist today, RPM could change healthcare delivery, which will enhance patient outcomes thus improving lives across the globe.

* **Corresponding author Akhil Sharma:** R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

Keywords: Artificial intelligence, Chronic, Clinical, Compliance, Digital health, Disease, Healthcare, Internet of things, Patient, Personalized medicine, Post-operation, Privacy, Recovery, Remote patient monitoring, Security, Wearable devices.

INTRODUCTION

Remote Patient Monitoring (RPM) is a healthcare practice that uses innovative technology for monitoring as well as managing patients' health from a different location. RPM merges wearable devices, mobile apps, telecommunication platforms, and other digital tools to track patients' signs of life, symptoms, and health parameters in non-traditional healthcare settings. Thus, this method enables healthcare practitioners to get current information about the condition of their patients; they can also detect diseases at an early stage and take necessary steps before they complicate or worsen the medical status [1].

The basic principle of RPM is that it gives patients the means to monitor their health and communicate with caregivers from home, thus enabling them to play a more active role in their treatment decisions. Often, RPM focuses on people with long-term ailments, the elderly, or those convalescing from surgery; it seeks to improve their lives, reduce the number of patients returning to hospitals more frequently, and lessen expenses for healthcare in general [2].

RPM components involve wearable sensors that monitor physiological parameters like heart rate, blood pressure, and glucose levels. They also include mobile applications that enable data gathering, transmission, and analysis. Other times, it may be a remote video consultation, prescription adherence monitoring, or personalized health coaching to support patients' self-management of their condition. A brief history of RPM is presented in Table 1.

The importance of RPM is that it allows people who live far away or in places with few services to get better access to care. For instance, RPM enables doctors to oversee patients' vital signs, signs, and adherence to medication, among others. By doing so, it helps identify complications at its earliest stages, hence reducing hospitalizations and improving long-term medical outcomes. Also, as the world's population ages rapidly, RPM meets the rising demand for health care, especially among elderly individuals suffering from multiple medical conditions [9].

RPM makes it possible to age in place and takes the burden off caregivers and health care institutions because it allows for proactive monitoring of seniors' health. Besides, RPM has been designed to facilitate preventive care and early intervention through patient empowerment for self-monitoring of vital signs as well as lifestyle choices. Prompt management is enabled by this type of

surveillance, preventing further development of diseases with less risk of developing further complications. Furthermore, RPM offers cost-effective healthcare delivery by reducing costly healthcare services such as hospitalization, emergency room visits, and avoidable medical procedures [10].

Table 1. Brief history of RPM.

Year	Milestone
1950s	Early experiments with telemetry systems for monitoring cardiac patients [3].
1960s	Development of the first wearable cardiac monitors for ambulatory patients [4].
1970s	Introduction of early telemedicine systems for remote consultations [5].
1980s	Advancements in telemetry technology enable remote monitoring of vital signs [6].
1990s	Expansion of RPM into chronic disease management, focusing on diabetes care [7].
2000s	Integration of RPM with mobile technology and electronic health records [7].
2010s	The rapid growth of the RPM market is driven by advancements in sensors and connectivity [8].
Present Day	RPM has become integral to healthcare delivery, transforming patient care [8].

Further, RPM inspires interactions between patients and healthcare providers, promotes self-management actions, and improves patient satisfaction with the healthcare experience. Finally, RPM produces huge volumes of patient data that can be studied to support clinical decision-making, develop personalized therapeutic plans, estimate health outcomes, and optimize care delivery pathways. Basically, RPM is a game-changing healthcare delivery method that provides advantages like increased accessibility to treatment, better management of chronic diseases, preventive healthcare, cost-effectiveness, patient involvement, and data-driven decision-making with regard to the future of healthcare delivery [11].

TECHNOLOGICAL ADVANCEMENTS

RPM is a very dynamic and evolutionary practice in healthcare that technological progress has supported. These developments include different creative solutions that boost RPM's efficiency, effectiveness, and accessibility [12 - 18]. Technological advancements in RPM are shown in Fig. (1).

IMPACT ON HEALTHCARE DELIVERY

The impact of RPM on healthcare delivery is profound. It has reshaped traditional models of care and ushered in a new era of patient-centric and proactive healthcare. Below and in Fig. (2), we describe ways in which RPM has transformed healthcare delivery.

AI's Inroad into Medication Enhancement

Sunita¹, Shaweta Sharma², Shekhar Singh³, S. Govindarajan⁴ and Akhil Sharma^{5,*}

¹ Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India

² School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

³ Faculty of Pharmacy, Babu Banarasi Das Northern India Institute of Technology, Lucknow, Uttar Pradesh, India

⁴ Department of Civil Engineering, Aditya University, Surampalem, India

⁵ R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

Abstract: AI and pharmaceutical improvement crossroads are an incredible opportunity in healthcare that can transform drug discovery, development, and delivery. AI-based approaches such as predictive modeling, pattern recognition, and mining of biomedical literature are some of the methodologies that can be accelerated for the identification of promising drug candidates. AI empowers drug design and synthesis by analyzing unstructured data and representing complex biological systems—such as protein folding. Automated laboratory processes (*i.e.*, drug testing or synthesis) lead to faster and more efficient cycles of research. Virtual screening, de novo drug design, and repurposing existing drugs are some of the ways AI applications can help in medication to result in more precise and effective therapies. Predictive analysis facilitates the evaluation of treatment responses whereas real-time monitoring systems guarantee the safety of drugs *via* early detection of adverse drug reactions. Targeted drug delivery systems enhance drug delivery and effectiveness, leading to better patient outcomes. Such advancements not only accelerate the exploration of drug discovery but also lead to better diagnostic accuracy, patient safety, and resource distribution to give rise to an economical health care model. However, the application of AI for drug development has its obstacles, including concerns about data privacy, ethics, and transparency in AI algorithms. To unlock the full potential promise of AI in healthcare, these roadblocks must be overcome. The next steps are further streamlining of AI algorithms to improve precision, greater incorporation of AI in clinical decision support, and the development of regulatory frameworks to ensure the safe and ethical use of AI across various facets of patient care. In this paper, we briefly outline how AI has transformed aspects of medication enhancement from the perspective of benefits to patient-oriented care; and express how its current challenges will nevertheless facilitate advances and opportunities in the future of healthcare.

* **Corresponding author Akhil Sharma:** R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

Keywords: Artificial intelligence, Discovery, De novo drug design, Healthcare, High-throughput screening, Machine learning, Medication, Nanotechnology, Pharmacovigilance, Personalized medicine, Predictive analytics, Patients, Precision, Robotics, Repurposing, Targeted.

INTRODUCTION

Artificial Intelligence (AI) in the health care industry means utilizing state-of-the-art computer programs and methods to examine challenging medical information, perform activities usually performed by humans, and assist in clinical judgment. With technologies such as machine learning, natural language processing, computer vision, and robotics, among others, they can deduce information from data, decipher patterns, and provide insights at rates much faster than humans [1].

Various fields in healthcare apply AI, such as interpreting medical images, drug discovery, personalizing treatment recommendations, predictive analytics, virtual health assistants, and automating administrative duties. To help doctors detect diseases, anticipate patients' prognoses, and design curative approaches that suit individuals with different backgrounds, AI systems process huge amounts of data from patients' Electronic Health Records (EHRs), medical imaging scans, genetic profiles, wearable devices, and other sources [2].

AI has the potential to completely change healthcare administration by increasing diagnostic accuracy, leading to more effective treatment modalities, improved operational efficiencies, and ultimately, better patient care outcomes. However, this comes with issues such as data privacy, regulatory compliance, algorithm transparency, bias mitigation, and ethical aspects, among other difficult questions that must be addressed continually to guarantee the responsible and fair implementation of AI within any health system [3].

There is an improvement in medication whereby drugs can be made to function better, safer, and easier to get. Enhanced medications also have the potential to improve treatment outcomes by enabling better targeting of diseases. Through AI-facilitated innovative drug discovery techniques, drugs can be tailored toward disease pathways, thus increasing their efficiency and possibly enabling reduced reliance on higher doses or a combination of different medicines [4].

Attempts to enhance drugs aim at reducing the negative impact of pharmaceutical therapies. Enhanced medications are designed to decrease the frequency and intensity of side effects by improving the drug formulations or focusing on particular biological pathways, thus making them safer and more bearable for patients. Improvements in medication enhancement strategy lead to the growth of personalized medicine where treatment is aligned with individual factors like

genomics, biomarkers, and behavior patterns. Thus, it enables accurate dosage determination as well as the choice of therapeutic interventions aimed at maximizing patient benefits while minimizing adverse outcomes [5, 6].

In the management of chronic diseases and prevention of their progression, improved medicines play a vital role. This kind of medication improvement may be able to slow down or stop the development of diseases by making drugs that are focused on reducing damage to the body. Medicines have typically been designed with due consideration to addressing specific disorders that are not currently covered within the medical sphere or those disorders for which there are limited therapeutic options. Innovations in technology and research have made it possible to develop better medications that can treat patients who were previously untreatable or undertreated due to certain conditions, thus filling up a void in healthcare provision [7, 8].

Enhancing drugs for optimization can make them less expensive and thereby reduce the need for frequent dosage or some adjunctive therapies and hospitalization. Enhanced medications improve treatment efficiency in health care, resulting in a balanced allocation of resources among healthcare systems. Medication enhancement is vital to advancing healthcare by improving treatment efficacy, safety, and accessibility aimed at unmet medical needs with a view to encouraging personalized, patient-centered care. This goal can be achieved only if there is greater investment in research and innovation towards medication enhancement, which will enable people's life spans to rise globally [9, 10].

Healthcare is being transformed by artificial intelligence across all levels, and this change is ultimately causing a revolution in the manner we diagnose, treat, and manage diseases. AI-supported diagnostics algorithms have significantly improved the way medical images are understood, ranging from X-rays to MRI scans. This has led to much more accurate and faster recognition of abnormalities that had not been seen before. As such, there is earlier diagnosis as well as intervention in conditions like cancer or neurological disorders. Also, AI has caused drug discovery and development processes to be completely different, hence considerably shortening the time frame involved in launching new drugs into the market [11].

AI can analyze large sets of data, determine which drugs may be useful, foresee how they will perform, and suggest molecular structures that could be optimized for better results. The system also enables medication customization by analyzing patients' genetic profiles, laboratory test results, or diagnoses. This innovative approach helps achieve better treatment outcomes with fewer side effects compared to conventional healthcare delivery strategies [12].

CHAPTER 6

IoT's Role in Revolutionizing Pillbox Technology

Shekhar Singh¹, Akhil Sharma², Sunita³, Sumit Chowdary Mukund⁴ and Shaweta Sharma^{5,*}

¹ Faculty of Pharmacy, Babu Banarasi Das Northern India Institute of Technology, Lucknow, Uttar Pradesh, India

² R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

³ Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India

⁴ Department of Civil Engineering, Aditya University, Surampalem, India

⁵ School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

Abstract: The incorporation of Internet of Things (IoT) technology into pillboxes means that there has been a great advancement in the field of drug management. Pill organizers have long been the main way to organize medicines. However, they mostly do not tackle adherence issues leading to poor treatment outcomes. Nevertheless, IoT-enabled smart pillboxes have completely transformed medication management by capitalizing on connectedness and data analytics to boost adherence and patient engagement. The chapter discusses the changes that have taken place in pill box technology from simple holders to IoT-based systems and the benefits and implications of these developments. Some of these include IoT integration, which provides wireless connections, sensors for real-time monitoring, and cloud-based data analysis, among others. There are various features such as personalized medication reminders, remote monitoring, and feedback that aid people in taking their prescribed medications as per the advice given by their doctors, thus lowering medication errors through enhanced adherence. Additionally, the use of Internet of Things technology in pillboxes provides patients with real-time feedback on their adherence behavior, and hence, they become more active participants in the management of their healthcare. The future of IoT-enabled pillbox technology with AI also anticipates personalization of medicine administration and expansion into other areas of healthcare. This chapter ends by calling for more research, collaboration, and policy support needed for enhancing the widespread adoption of IoT-based healthcare solutions and optimizing medication consumption to promote better patient care outcomes.

* **Corresponding author Shaweta Sharma:** School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India; E-mail: shawetasharma@galgotiasuniversity.edu.in

Keywords: Artificial intelligence, Clinical, Chronic, Compliance, Disease, Digital health, Healthcare, Internet of things, Post-operation, Privacy, Patient, Personalized medicine, Recovery, Remote patient monitoring, Security, Wearable devices.

INTRODUCTION

Medication management has become more complicated in today's healthcare. Patients have a difficult time adhering to them, which leads to negative health outcomes and increased expenditures on healthcare. Luckily, technology advancements have been made, especially in the Internet of Things that could help promote medication management further. This chapter discusses how IoT has revolutionized medication management through its integration into pillbox technology [1, 2].

IoT is a network of interconnected devices embedded with sensors, software, and other technologies that enable them to exchange data and communicate over the Internet. In various industries, including healthcare, IoT has gained immense popularity as it enables remote monitoring, data collection, and analysis for improved patient care and operational efficiency [3 - 5].

IoT has greatly transformed pillbox technology from a mere container for the arrangement of drugs to an intelligent product. In particular, smartness is achieved by adding sensors, making it connectible, and installing mobile applications that work with it to monitor and control compliance with medication. Thus, these applications have features such as automated reminders, tracking dosing and synchronizing information with healthcare providers [6].

The most important thing about IoT-connected pillbox technology is that it increases the levels of adherence to medication. Smart pillboxes offer notifications and reminders to help patients follow the prescription times that have been personalized for them. Additionally, real-time monitoring features allow doctors to intervene early in case of non-adherence; this has the effect of improving treatment outcomes generally [7, 8].

IoT-enabled pillboxes allow monitoring of the medication adherence of patients from afar, enabling healthcare providers to determine whether they are adhering to prescribed medication. This kind of remote support system allows for immediate changes in therapy, thus helping to reduce chances for complications and hospital stays. Furthermore, patients are more confident knowing their healthcare team's continuous involvement with their lives, thus leading to a higher degree of participation and pleasure [9, 10].

The integration of IoT in pillbox technology has various challenges and issues that must be addressed despite its potential as a transformative tool. These include concerns over the safety of data, compatibility with existing medical systems, and the elderly or technically unsophisticated who seek to reach it. Collaboration involving healthcare providers, developers of technology, regulatory bodies, and patients is needed to address these challenges [11].

However, the incorporation of IoT in pillbox technology has a number of problems and factors that should be considered. It should be noted that these may include issues about data protection and security, compatibility with other health systems, and availability to older people or those who are not technically advanced. Dealing with those difficulties necessitates the engagement of a wide range of participants such as healthcare professionals, computer scientists, government authorities in charge of regulations, and patients themselves [11, 12].

The inclusion of IoT in pill box technology is a deviation from the usual method of handling medicine; thus, it provides contemporary ways through which medication adherence can be improved, remote monitoring can be done, and data can support a decision-making process. By connecting people with real-time information and using analytics, smart pillboxes can change patient care, resulting in improved treatment results. Nevertheless, for this potential to be realized, several obstacles that touch on confidentiality issues and others pertaining to interoperability must be addressed. Through cooperation among interested parties in this area, everyone may fully exploit these advantages tied to an IoT-incorporated pillbox technology, hence transforming healthcare delivery across the globe [13, 14].

PILLBOX TECHNOLOGY EVOLUTION

Historical Perspective on Medication Adherence and the Need for Innovative Solutions

Medication adherence in the health care system remains a challenge as patients follow prescription treatment patterns. Medication non-compliance results in worsened health outcomes, escalated medical service expenses, and an erosion in quality of life. Even with progress made in medical practice, aiming at optimal compliance is still impossible. This historical review looks at medication adherence and presents the factors that impact it alongside the identification of creative measures required to tackle this matter decisively [15 - 18].

In ancient times, people used to administer medications in the form of herbal mixtures, lotions, and mysterious liquids; therefore, this concept has existed since then. Although these remedies were not based on scientific research and were

CHAPTER 7

Personalized Medicine: AI-Driven Prescription Plans

Neeraj Kumar Fuloria¹, Akhil Sharma², Ashish Verma³, S. Ananda Kumar⁴ and Shaweta Sharma^{5,*}

¹ Department of Pharmaceutical Chemistry, Faculty of Pharmacy, AIMST University Semeling Campus, Bedong, Kedah, Malaysia

² R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

³ Mangalmay Pharmacy College, Plot No. 9, Knowledge Park II, Greater Noida, Uttar Pradesh, India

⁴ Department of Civil Engineering, Aditya University, Surampalem, India

⁵ School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

Abstract: In healthcare, personal medicine has changed dramatically through AI growth. This chapter explores the link between personalized medicine and AI prescription plans, outlining the current status, challenges faced, and future implications of these systems. This approach is essentially based on a personalized medicine system where therapies are adjusted to suit individuality traits like genetic makeup, lifestyles, and environmental factors. The traditional approach of one size fits all used in the field of health may not be comprehensive enough to fit all the patients' needs. However, personalized medicine utilizes AI to analyze huge amounts of patient data and produce individualized plans that enhance treatment efficiency and reduce unfavorable reactions. AI assists in precision oncology, drug discovery, and treatment optimization with notable initiatives like IBM Watson for Drug Discovery, AiCure for medication adherence, and Pillo Health for patient engagement demonstrating its promise. AI makes patients feel more empowered and involved in healthcare decisions using patient-centric tools, such as shared decision-making platforms, personalized educational content, and support communities. Various sources of data are integrated and combined with AI-driven decision support systems that provide accurate diagnoses, risk predictions, and personalized care plans. Implementing these innovations depends on economic and societal implications, such as cost-effectiveness and equitable access to humanized personalized treatments. To unleash the full potential of AI, data privacy, algorithmic transparency, how it will fit into the overall health market ecosystem, and other challenges must be addressed. Looking ahead, AI integration in personalized medicine has better patient outcomes, generates real-world evidence, and paves the way for a more efficient and focused patient healthcare system.

* **Corresponding author Shaweta Sharma:** School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India; E-mail: shawetasharma@galgotiasuniversity.edu.in

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This chapter outlines the fundamentals of the transformative effect of AI, including its modality-specific applications, advantages, and prospective trends of development in personalized medicine.

Keywords: Artificial intelligence, Google deep variant, Genomic data, Health, IBM Watson, Medicine, Medication, Patient, Personalized, Treatment.

INTRODUCTION

Personalized medicine, also known as precision or individualized medicine is a new healthcare approach that involves customizing medical treatments and prevention strategies to individual patients. The fact that individuals react differently to medicines, treatments, and intercessions is acknowledged by this approach. This may be due to genetic constitution, lifestyle choices, environmental exposures, or other personal attributes [1, 2].

The ultimate goal of personalized medicine is to achieve maximum effectiveness with minimum harm by focusing on the specific biological, genetic, and environmental factors that affect a person's health and disease risks. Modern technologies such as genomics, proteomics, metabolomics, and bioinformatics are exploited in the effort to identify biomarkers and genetic variants that contribute towards disease progressions, treatment responses, as well as risk [3, 4].

A treatment plan, or prescription plan, is a fundamental part of healthcare delivery that explains the steps to be taken in managing an illness or health condition. Prescription plans mean that the right medicine is prescribed at the right dose for an individual patient's diagnosis and medical history. This ensures that appropriate pharmacotherapy is administered to reach therapeutic targets. A prescription plan gives a complete approach to handling the patient's condition, thereby facilitating collaborative care among healthcare givers by outlining this approach. As such it may entail multidisciplinary collaboration, referral of patients to consultants, or integration of other services such as physiotherapy or counseling [5].

Patients are given instructions about drug use, changes in lifestyle, and how to manage themselves under prescription plans. By giving patients the necessary information and tools, these plans make sure that they adhere to medication as well as participate actively in their own care which is fundamental for effective treatment. Prescription plans are fluid documents that need to be reviewed periodically and adjusted according to a patient's response to therapy, change in health status, or new clinical guidelines. This will ensure that interventions

continue to be relevant and useful by making it possible for the regimen to be modified on a routine basis depending on the changing needs of the patient [6].

Integration of AI in the tailoring of treatment plans is helping to make personalized medicine more accurate and impactful through the use of advanced analytics and decision support tools. Prescription plans are crucial in turning individualized treatment recommendations into workable strategies that are aimed at optimizing patient outcomes and improving overall treatment effectiveness [7, 8].

GOALS OF PERSONALIZED MEDICINE

The basic principles, objectives, and application of personalized medicine in the larger healthcare setting must be well understood. These aims of personalized medical services are focused on different directions that should change traditional ways of giving out health care to become more patient-centered [9, 10]. The primary goals of personalized medicine are elaborated below and summarized in Fig. (1).

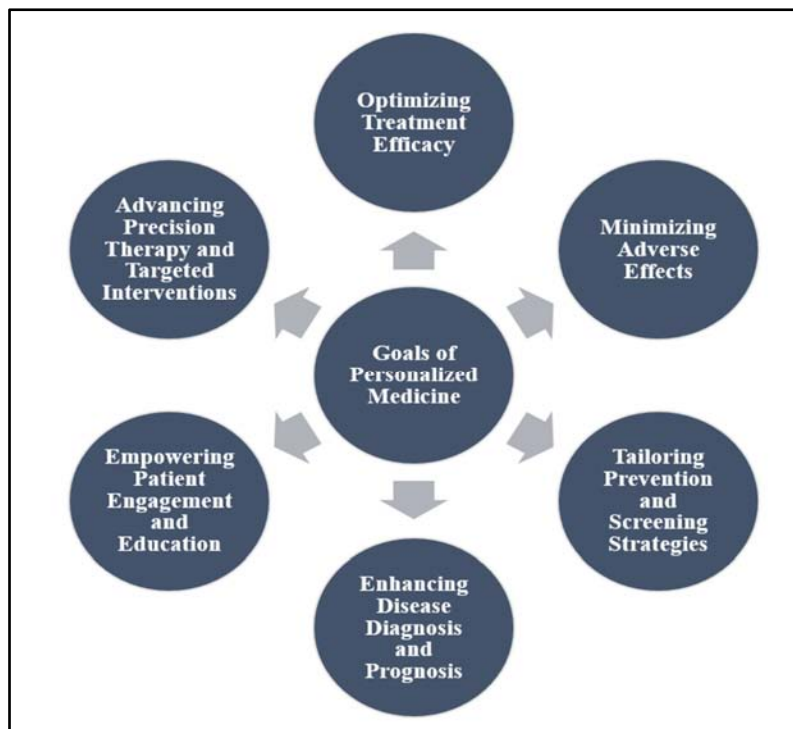


Fig. (1). Primary goals of personalized medicine.

CHAPTER 8

Real-Time Tracking with IoT Sensors Revolutionizing Healthcare System

Shivkanya Fuloria¹, Akhil Sharma², Akanksha Sharma², B. Rama Mohana Reddy³ and Shaweta Sharma^{4,*}

¹ Department of Pharmaceutical Chemistry, Faculty of Pharmacy, AIMST University Semeling Campus, Bedong, Kedah, Malaysia

² R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

³ Department of Civil Engineering, Aditya University, Surampalem, India

⁴ School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

Abstract: A transformative revolution has been triggered by the inclusion of Internet of Things (IoT) sensors in healthcare's real-time tracking capabilities. Recent advancements in miniaturization and low-power designs, wireless connectivity, and sensor fusion (integration of information from multiple sensors) continue to have a profound impact on the monitoring of health. Intelligent embeddability and superior sensing capabilities facilitate seamless patient data tracking, and strong security protects data against breaches. The role of IoT sensors in healthcare is to connect devices, such as biometric and temperature sensors or imaging and environmental sensors. IoT sensors are used in multiple applications such as fitness and vital signs tracking information, and patient care in smart healthcare facilities. Such technologies enable IoT-based medication adherence systems so that patients follow prescribed treatments, thus improving outcomes and reducing the possibility of hospital readmissions. Compared to regular monitoring devices, IoT sensors provide continuous data capture, increased accuracy, improved patient mobility and personalized healthcare solutions. Healthcare IoT adoption faces challenges in data privacy, regulation, and the complexity of technical integration of healthcare IoT in existing infrastructures. Ethical considerations must also be addressed to ensure equitable access and unbiased use of IoT technology. However, despite these obstacles, the future of IoT-based healthcare technologies remains an attractive proposition with continuous technology evolution likely to improve the quality of care, optimal resource allocation, and decision-making in real-time. This chapter explores the evolution of healthcare monitoring through IoT sensors, detailing their technological mechanisms, applications, benefits, and the potential for transforming the healthcare landscape.

* Corresponding author Shaweta Sharma: School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India; E-mail: shawetasharma@galgotiasuniversity.edu.in

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Keywords: Abnormality, Blood pressure, Disease, Heart rate, Healthcare, Implant, Internet of things, Patient, Real-time, Remote, Sensor, Technology, Wearable.

INTRODUCTION

The Internet of Things (IoT) is a system where devices are connected to each other, and they can communicate among themselves. It is a huge step towards the creation of smart environments. In healthcare, IoT has many implications, like enabling real-time health monitoring and data access which eventually results in better patient health experience and improved healthcare operations [1, 2].

Simultaneous report and monitoring, data collection and analysis, and end-to-end connection can be improved by IoT in healthcare. Examples of medical devices that are based on IoT include remote patient monitoring, smart inhalers, swallowable sensors, mood tracking, sugar level tracking, heart rate watching; smart contact lenses; robot surgery, and Parkinson's disease identification [3, 4].

Real-time health monitoring, data access, and enhanced healthcare operations are some of the major ways in which IoT could transform patient care. Remote monitoring *via* IoT sensor technologies can help improve medication management and enhance operational efficiency. However, ethical guidelines must be put in place by healthcare providers and policymakers to deal with challenges such as cost, usability, and data security so that this potential can be fully utilized [5, 6].

Real-time healthcare monitoring is a concept that requires the use of IoT devices like wearables and other wirelessly connected devices in order to collect patient health data constantly. The information can range from physical conditions such as blood pressure, heartbeat rate, and glucose levels as well as sleeping patterns. In summary, this type of monitoring enables medical staff to monitor patients' health status for quick response to any abnormality detected that may lead to better treatment outcomes and lower healthcare costs in the end [7, 8].

The idea behind real-time healthcare monitoring is that it uses Health Monitoring Systems (HMS) that take physiological measurements using biosensors, get important attributes and measures from the output, and analyze records right away. Therefore, the main intent of HMSs is to observe the patient's health condition and identify abnormalities timely in advance leading to an intervention beforehand and enhancing patient welfare. This makes IoT-based healthcare monitoring systems very useful because they allow secure, real-time remote patient monitoring, thereby making it easy for doctors to obtain real-time data [9, 10].

These systems can monitor various parameters such as heart rate, blood pressure, blood glucose levels, and sleep patterns so that real-time data can be analyzed for informed patient care decision-making by health workers. Smart real-time healthcare monitoring and tracking systems using GSM and GPS technologies can provide an effective system model that tracks, traces, and monitors patient vital readings in order to offer efficient healthcare services [11].

Such systems can facilitate real-time monitoring of the health status of patients by healthcare providers, early detection of anomalies, and intervention in a timely manner, thus improving patient outcomes while reducing healthcare costs. Real-time sickness detection and constant monitoring of patients' health state are some of the benefits associated with Remote Patient Monitoring Systems (RPMS). Quick medical attention can be provided by the RPMS in case death that would occur untimely is detected making its performance in treatment better. RPMS also assists in the management of chronic diseases, enhancement of medicine administration as well as minimizing rates at which patients revisit hospitals [12].

These devices, such as wearable and connected medical devices use IoT to collect real-time health data, which can inform timely interventions in chronic diseases like COPD, asthma, or heart failure. By using IoT technology, healthcare providers will develop a more effective, patient-focused, and integrated healthcare system [13].

Additionally, IoT makes it possible to collect and analyze data in real time, thus giving medical service providers a wide range of information on the condition of patients. The approach based on this data can be the basis for personalized care plans and timely interventions. Besides, having more information will enable physicians and other healthcare professionals to get a better understanding of patients' behavior, preferences and patterns hence making care given to patients more individual [14].

One other significant advantage of IoT in healthcare is that it fosters smoother workflows and operational efficiency. For instance, there are smart beds and asset tracking systems linked through the internet that will optimize resource utilization, minimize errors, and automatically perform routine duties. This leads to savings on costs by healthcare facilities, as well as improved output by the staff and more efficient delivery of health services [15].

Preventive and predictive healthcare is also facilitated by IoT through continuous monitoring of patient data, recognizing early warning signs, and enabling proactive interventions for better healthcare decision-making. Additionally, medication management and adherence are improved through IoT-enabled smart pill bottle dispensers, medication tracking systems, and wearable reminders [16].

CHAPTER 9

Ensuring Dosage Adherence in the Digital Era of IoT and AI

Shaweta Sharma¹, Dimple Singh Tomar², Sunita³, K.K. Yashwanth⁴ and Akhil Sharma^{5,*}

¹ *School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India*

² *Kharvel Subharti College of Pharmacy, Swami Vivekanand Subharti University, Meerut, India*

³ *Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India*

⁴ *Department of Civil Engineering, Aditya University, Surampalem, India*

⁵ *R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India*

Abstract: A major issue in healthcare is to guarantee that people take their medication regularly. This leads to non-adherence, which in turn results in health problems, high healthcare expenditure, and reduced quality of life among the patients themselves. In this digital world, a combination of the Internet of Things and Artificial Intelligence creates an opportunity that has never been seen before and can be used to tackle these challenges effectively. In this chapter, we will explore the role of IoT and AI in improving medication compliance by outlining some promising benefits, difficulties faced as well as implications for future practice. The use of IoT enables remote monitoring systems that enable medical practitioners to keep track of when drugs are taken instantaneously and remotely. The wearable devices integrated with the internet of Things can check the life signs and how medicine works, thereby offering vital signs on patient health and adherence patterns. Additionally, smooth interconnection with electronic health records enables information sharing and better care integration. Personalized interventions and predictive analytics serve as an ideal complement to IoT from AI. AI-driven systems provide customized alerts and notifications based on the patient's individual profile, preference, and behavioral pattern. Predictive algorithms analyze massive data in order to recognize adherence tendencies as well as potential risk factors, thereby making it possible for proactive interventions designed to avert non-compliance-related complications. Chatbots that are AI-enabled offer continuous assistance in addressing patients' questions regarding medications. However, the current advent of IoT and AI comes with several obstacles. Patient trust and compliance should be considered when it comes to ethical data protection and privacy. Again, to use them effectively, these technologies must be trained by many healthcare

* **Corresponding author Akhil Sharma:** R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

experts and patients, and they must be educated adequately on this matter. In addition, regulatory frameworks need to change swiftly in order to incorporate digital healthcare advancements while striking a balance between innovation and patient safety/privacy. Finally, utilizing IoT together with AI can greatly help secure medication adherence in the digital era. Healthcare providers can heal patients faster, reduce medical expenditures, and improve overall care quality by using these abilities further. Embracing innovation and collaboration among various stakeholders in healthcare is essential if we are going to maximize the full potentiality of IoT and AI regarding medication adherence.

Keywords: Adherence, Disease, Dosage, Digital, Health, Healthcare, Medicine, Patient.

INTRODUCTION

Dosage adherence means the extent to which a patient follows properly the prescribed dose instructions for medication, such as the dose amount, frequency, timing, and duration of treatment. This is an important aspect of medicine-taking behavior that needs to be addressed if patients are to take their medications optimally in order to achieve therapeutic goals and improve health outcomes. Not following dosage instructions correctly can lead to lowered clinical benefits, increased healthcare expenses, and may even deteriorate a patient's condition. Thus, dosage adherence is a critical factor for the efficacy of treatment regimens and the overall well-being of the patient [1, 2].

The digital age can be seen as a time when advanced technologies are growing at a very fast rate. Also, this technology is becoming part of every aspect of society, business, and daily life. These two technologies are the Internet of Things and Artificial Intelligence, which have been instrumental in changing this era. The expression "Internet of Things" (IoT) refers to the interconnection *via* the internet of computing devices embedded in everyday objects, enabling them to send and receive data. Consequently, this has resulted in the formation of a vast network that interlinks everything from cellphones, watches, and refrigerators to entire cities [3, 4].

Artificial Intelligence (AI) is a term used to describe machines performing tasks that would usually demand human intelligence to do, like learning, problem-solving, pattern recognition, understanding of natural language, and decision-making. In the IoT, AI can analyze consumer behavior and search data through emails, blogs, and social media platforms on how users connect with their products and services [5].

IoT coupled with AI is a powerful combination that can revolutionize our approach to different domains like digital marketing, healthcare, and

transportation. In this regard, businesses can gain access to a wealth of data by capitalizing on the vast number of interconnected devices that comprise the IoT. It is up to AI to make such insights actionable by converting them into data sets, which have an uncanny ability to predict the behavior of consumers and guide their personalization. This blending of IoT with AI will lead to real-time customer engagement, predictive analysis, AI-powered chatbots, and a major focus on data safety, creating a giant leap in the field of digital marketing. In the healthcare sector, IoT devices enable businesses to interact with customers in real-time, thereby providing unique personalized experiences that hold the attention of customers. For instance, fitness trackers collect information about physical activities carried out by a person's sleep patterns, among other health aspects, allowing doctors to give individualized advice or treatment options as required [6, 7].

AI and IoT can boost safety, communication, and data collection in the transportation industry. Some examples of this are adaptive cruise control, self-driving cars, and see-through pillars that the automotive industry is deploying to make automobiles more secure and economical. Society and commerce have been revolutionized by the digital age, as well as IoT and AI, thus bringing personalization, efficiency, and innovation, among others. By using these technologies wisely, businesses can obtain useful information that will enable them to make good choices regarding products or services that suit their customers [8, 9].

Adherence to dosage is a significant aspect of healthcare, as it greatly affects the efficiency of medication and the general health of the patient. Adherence refers to how much a patient follows a treatment plan, including taking medication as prescribed with respect to dose, dosing interval, duration of therapy, and other particular instructions given [10]. Failure to follow medical instructions may be associated with negative consequences such as rates of disease progression, decrease in functional capabilities, poor quality of life, increased utilization of medical resources, and eventually even death. In the US alone, non-adherence causes approximately 125000 deaths annually from cardiovascular diseases; up to 23% of nursing home admissions (10% hospitalization), many doctor visits, laboratory tests, and unnecessary treatments would be avoided if patients took their medications as directed [10, 11].

Adherence is influenced by various factors such as patient attitudes and personal traits, disease features, social situations, access to services, poor communication between healthcare providers and patients, lack of knowledge about a drug and its administration, no belief in the necessity of treatment, dread of the side effects of drugs, prolonged use of drugs, complicated prescriptions with numerous

CHAPTER 10

Seamless Integration of Technology in Pharmaceuticals

B. Rama Sagar¹, Akanksha Sharma⁴, Shaweta Sharma², Shekhar Singh³ and Akhil Sharma^{4,*}

¹ Department of Civil Engineering, Aditya University, Surampalem, India

² School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

³ Faculty of Pharmacy, Babu Banarasi Das Northern India Institute of Technology, Lucknow, Uttar Pradesh, India

⁴ R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

Abstract: The pharmaceutical industry is the most innovative of all industries due to the integration of technology into its main operations. This chapter examines the impact of technology on pharmaceuticals and highlights some significant achievements as well as their consequences. Revolutionizing the development, discovery, and delivery of drugs by pharmaceutical companies is taking place through the convergence of advanced technologies like Artificial Intelligence (AI), big data analytics, automation, and the Internet of Medical Things (IoMT). The streamlining of manufacturing processes through automation and robotics has enhanced their efficiency and guaranteed accuracy in drug formulation and packaging processes. Meanwhile, big data usage has unveiled very essential information from large datasets, which accelerated the discovery of drugs, identifying new targets, predicting drug interactions, and optimizing clinical trials. AI and Machine Learning (ML) algorithms are giving researchers the ability to develop models that can predict drugs quickly and more accurately. IoMT has made it possible to monitor patients' real-time health metrics from connected devices and sensors, enabling personalized medicine as well as remote patient care. Nevertheless, there are regulatory issues around data privacy, security, and interoperability. To exploit the full potential of technology in pharmaceuticals while maintaining patient safety and privacy, a balance must be struck between innovative ideas and compliance needs. It also highlights the ethical issues that are associated with technology integration, focusing on the significance of ethical frameworks that guide responsible innovations. Further developments in pharmaceutical research, development, and healthcare delivery depend on the industry's capacity to adapt to new technologies and surmount difficulties related to these technologies. The pharmaceutical landscape is bound to change significantly with

* **Corresponding author Akhil Sharma:** R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

the help of technology integration, which promises a new era of precision medicine-improved patient outcomes through collaboration, innovation, and ethical stewardship.

Keywords: Analytics, Artificial intelligence, Automation, Big data, Drug, Health, Internet of medical things, Internet of things, Medication, Machine learning, Medicine, Patient, Personalized medicine, Robotics, Treatment.

INTRODUCTION

The seamless assimilation of pharmaceuticals involves the harmonious blending of various technological advancements and processes within the pharmaceutical industry to create a cohesive and efficient ecosystem. It consists of the smooth and efficient integration of technologies like automation, data analytics, artificial intelligence, and interconnected devices, among others, in all the stages of drug development, manufacturing, distribution, and patient care [1, 2].

This integration is intended to scrap silos and optimize workflows so as to realize more collaborations and synergies between different departments and stakeholders involved in pharmaceutical operations. By ensuring that technology is merged with this sector, efficiency can be achieved, drug discovery timelines will take a shorter period, product quality can improve, and ultimately, patient healthcare outcomes will be enhanced [3, 4].

Seamless integration also ensures that different technology platforms and systems can work together, making it possible for data to be exchanged across the pharmaceutical value chain without any break. Through this network of interconnections, instantaneous decision-making is enabled in addition to personalized medicine approaches and continuous process improvements [5, 6].

The importance of technology in modern pharmaceutical practices cannot be overstated. Several key reasons why technology plays a vital role in the pharmaceutical industry are discussed below and shown in Fig. (1).

The advancement of technology has allowed drug discovery to adopt advanced computational approaches, such as virtual screening, molecular modeling, and simulation. Researchers are able to evaluate vast datasets and more accurately predict drug-target interactions using high-performance computing for faster discovery. Massive amounts of data are generated by the pharmaceutical industry from clinical trials, research studies, patient records, and genomic information. Technology has made it possible to collect, store, and analyze this data, thus revealing information that can be used in decision-making, optimizing the design of clinical trials, and indicating new therapeutic targets [7].



Fig. (1). Role of technology in pharmaceutical industry.

Progressions in technology have given rise to personalized medicine, for example, the ability to read genes and identify biomarkers. Diagnosis and treatment of diseases can be made by analyzing an individual's genetic profile, among other patient-specific details, so that the correct care is provided for every patient, thus minimizing side effects while enhancing efficiency [8]. Robotics and automation have turned around the pharmaceutical manufacturing processes by enhancing effectiveness, lowering mistakes, and ensuring product uniformity. Examples of technically driven advances include continuous processing and real-time monitoring systems that help to scale up production, reduce wastage, and improve compliance with regulations [9].

Supply chain optimization technology plays a vital role in sourcing raw materials, distribution, and logistics. Advanced software systems, such as those that allow inventory tracking in real-time, demand forecasting, temperature-controlled product management, *etc.*, are important to ensure the safe and efficient delivery of pharmaceutical products to patients worldwide. Mobile apps, wearable devices, and telemedicine platforms are some of the digital health technologies that enable patients to take charge of their healthcare processes. These gadgets allow remote

CHAPTER 11

Healthcare Outcomes Amplified by Data Insights

N. Bhaskara Rao¹, Shaweta Sharma², Sunita³, Akanksha Sharma⁴ and Akhil Sharma^{4,*}

¹ Department of Civil Engineering, Aditya University, Surampalem, India

² School of Medical and Allied Sciences, Galgotias University Plot No. 2, Yamuna Expy, Opposite Buddha International Circuit, Sector 17A, Greater Noida, Uttar Pradesh, India

³ Metro College of Health Sciences and Research, Greater Noida, Uttar Pradesh, India

⁴ R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India

Abstract: The level of success in healthcare can be assessed by patient care improvements, treatment efficiency, and overall quality of health provision. The aim of clinical outcomes is challenging and influenced by several factors, such as patient demography, disease profile, treatment methods, and healthcare delivery systems. Over the past years, there has been an increase in healthcare information available and new ways to improve outcomes through data-driven decisions. This chapter is about how data insights can improve healthcare outcomes. It starts by explaining why healthcare outcomes are important in gauging the effectiveness of health interventions. Problems associated with health care delivery, such as different responses to treatment, escalating costs, and gaps in access to services, will be explored throughout this chapter. Healthcare providers can obtain useful information regarding trends in patient health, treatment effectiveness, and disease evolution when they use data from varied sources such as electronic health records, medical imaging, and wearable devices. Consequently, this acquired evidence enhances decision-making, personalized treatment approaches, and proactive interventions to optimize healthcare outcomes. The use of data insights ranging from predictive analytics for early disease detection to personalized medicine based on individual genetic profiles gives an unprecedented opportunity to improve patient outcomes, reducing clinical workflow redundancy and minimizing overall healthcare budgets. However, the chapter also recognizes the ethical, legal, and technical challenges of leveraging healthcare data. Concerns regarding patient privacy, data security, and algorithmic bias must be addressed to realize the full potential of data-driven healthcare. In conclusion, the chapter highlights the transformative impact of data insights into healthcare outcomes and calls for continued investment and innovation in data-driven approaches to improve patient care and population health.

* Corresponding author Akhil Sharma: R.J. College of Pharmacy, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh, India; E-mail: xs2akhil@gmail.com

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INTRODUCTION

The healthcare system's cornerstone is healthcare outcomes, which are the results and repercussions of medical interventions, treatments, and healthcare services. The efficiency, efficacy, and quality of care delivered can be assessed by these outcomes and their impact on patients' health welfare as well as the overall performance of the health systems [1].

The essence of healthcare outcomes is their ability to ascertain the effectiveness of clinical treatments. They serve as indices by which healthcare practices can measure their goal attainment in terms of patients' health. Healthcare intervention outcomes give important insights into the effectiveness of different treatment and therapeutic approaches for managing chronic conditions, preventing diseases, or treating acute illnesses [2].

Healthcare outcome is still the major determinant in the overall assessment of healthcare service quality. As a result, this allows healthcare professionals and institutions to evaluate their performance on specific clinical guidelines and best practices. Healthcare entities can identify areas that need improvement and adopt evidence-based practices through outcomes, enabling them to improve patient safety [3].

Healthcare outcomes have broader implications for healthcare system performance and public health beyond individual patient encounters. Policymakers and public health officials can evaluate the effectiveness of public health interventions, healthcare policies, and preventive measures through monitoring population-level outcomes. It helps them allocate resources efficiently, make informed decisions, and address health disparities to enhance overall population health outcomes [4].

Moreover, healthcare results are intimately connected to the satisfaction and experiences of patients. Such positive outcomes include enhanced health, relief from symptoms, and a better quality of life, which patients value in healthcare encounters. These positive outcomes lead to long-term loyalty and relationships between patients and healthcare providers or systems [5].

Besides making patients feel better, good results in healthcare can save costs to both patients and health systems. Better health outcomes may reduce the need for medical interventions, drugs, and hospital stays, thus lowering healthcare costs.

Likewise, by focusing on interventions and practices that result in a positive outcome, healthcare facilities can optimize resource utilization and minimize this unnecessary use of health services [6].

On the other hand, negative results in health care may also be disadvantageous for patients, healthcare providers, and systems at large. For instance, outcomes below standard can result in extended sicknesses, disabilities, or complications among individuals, thereby leading to reduced living standards and increased medical expenses. These results potentially reduce patients' trust in healthcare workers and organizations, thus hampering patient-focused service provision [7].

The concept of data-driven insights has become a powerful tool across industries, including healthcare, in today's society. Data insights are meaningful information that can be acted upon, derived from analyzing huge amounts of data. Such perspectives or patterns revealed by this correlation may help organizations make decisions, foster innovation and identify areas for growth [8].

Healthcare data insights are useful in enhancing patient outcomes, transforming care delivery, and optimizing healthcare operations. Healthcare providers and organizations can learn more about the health condition of patients, trends in diseases, effectiveness of treatment, and patterns of healthcare use by utilizing the abundant health data produced within systems like Electronic Health Records (EHRs), medical imaging, genetic information, and patient-generated data [9].

Clinical decision-making is an important area where data insights can make a major difference. Healthcare providers can use data analytics and machine learning algorithms to analyze patient data and formulate personalized treatment plans for the patient's specific needs. For instance, prediction models based on analytics can help identify persons with a high chance of developing certain diseases or experiencing adverse events, thereby facilitating preventive interventions and proactive steps that enhance patient results [10].

Further, data analytics can enable evidence-based medicine by transforming clinical data and research into practical guidelines for medical practice. Medical personnel can access extensive databases and clinical decision support systems that offer real-time recommendations and guidance using current medical information and treatment techniques. This ensures that patient care is consistent with contemporary norms and regulations, enhancing better clinical results as well as the safety of patients [11].

Data insights have extensive implications for population health management and public health surveillance beyond clinical care. Public health agencies and healthcare organizations can use population-level data to discover patterns of

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Akhil Sharma

Akhil Sharma, M. Pharm., Ph.D., is presently working as professor and principal at R.J College of Pharmacy, Raipur, Aligarh, U.P., India. He completed Ph.D. in 2016 from Teerthanker Mahaveer University, Moradabad, U.P., India. He has been serving in pharmacy for more than 15 years. He has published articles in many peer-reviewed national and international journals.



Neeraj Kumar Fuloria

Neeraj Kumar Fuloria is a distinguished academician and researcher with over 23 years of experience spanning academia, research, and industry. He is a professor at the Pharmaceutical Chemistry Unit, Faculty of Pharmacy, AIMST University, Malaysia, and an adjunct professor at the Center for Trans-disciplinary Research, Saveetha Medical College & Hospital, India. He holds multiple prestigious qualifications, including B. Pharm, M. Pharm, Ph.D. in pharmacy, an MBA, and a PDCTM, demonstrating his interdisciplinary expertise. He has 241 publications, including 204 research papers with a cumulative impact factor of 456.626, 16 patents, and multiple book contributions, he has significantly contributed to pharmaceutical sciences. He has successfully supervised multiple Ph.D., postgraduate, and undergraduate research projects and has secured 9 national and international research grants. His research excellence is reflected in his H-index of 48 with 7,429 citations (Google Scholar). He has received several prestigious accolades, including the "2% Scientist List 2023" (Stanford University), "Young Scientist Award 2022," and "Inspirational Scientist Award 2020."



Pankaj Kumar Singh

Pankaj Kumar Singh is a TCSMT postdoctoral researcher at the Institute of Biomedicine, University of Turku, Finland. With a strong academic background, he holds a Ph.D. in pharmaceutical sciences (medicinal chemistry) from Punjabi University, Patiala. His research expertise includes molecular dynamic simulations, computer-aided drug design (CADD), and synthetic organic chemistry, with a focus on histone methyltransferase modulators, peptide-based macrocycles, and kinase inhibitors for cancer therapy. He has contributed significantly to the field through postdoctoral research collaborations in Italy and Finland. He has also been actively involved in teaching, delivering courses in biochemistry, biomolecules, and drug chemistry at various institutions. His scholarly contributions extend to serving as a reviewer for esteemed journals such as the European Journal of Medicinal Chemistry and Drug Discovery Today. Recognized for his impactful research, he has been listed among the Top 2% Scientists by Stanford University and Elsevier.



Shaweta Sharma

Shaweta Sharma, M. Pharm., Ph.D., is currently employed as professor at Galgotias University, Greater Noida. She completed Ph.D. in 2017 from Teerthanker Mahaveer University, Moradabad, U.P., India. She has been contributing to academics for more than 15 years. She has published articles in many peer-reviewed national and international journals.