

TECHNICAL ADVANCES IN PHARMACY AN OVERVIEW

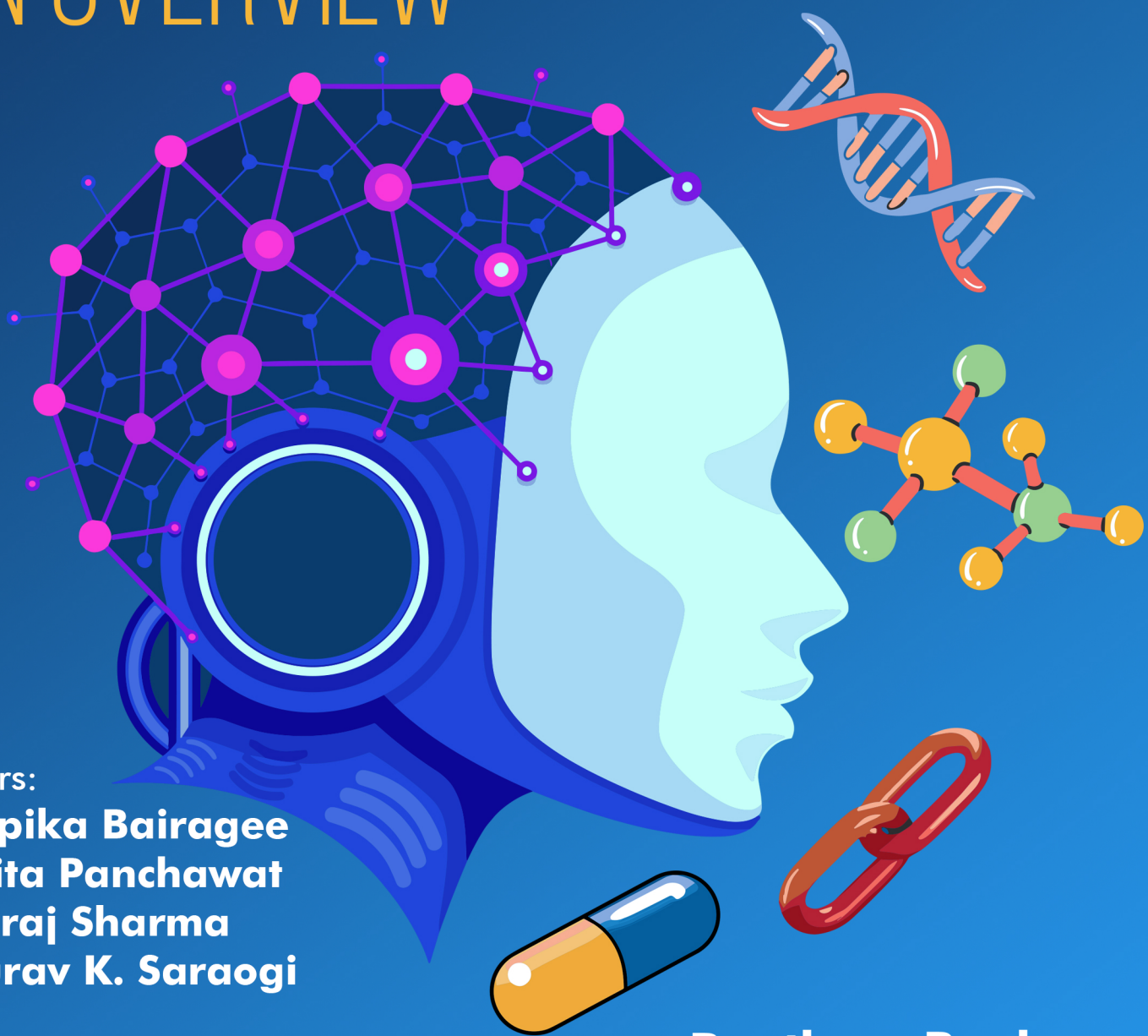
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Technical Advances in Pharmacy: An Overview

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Technical Advances in Pharmacy: An Overview

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PREFACE

The field of pharmacy is witnessing a revolutionary transformation fueled by cutting-edge technologies and innovative methodologies. As the demands of healthcare evolve, so must the tools and techniques used in pharmaceutical sciences. This book, *Technical Advances in Pharmacy: An Overview*, provides a comprehensive exploration of emerging trends and technologies shaping the future of pharmacy practice, research, and education.

Each chapter delves into a specific domain where technology intersects with pharmacy, beginning with the pivotal role of Artificial Intelligence (AI) in drug discovery, accelerating the identification of new therapeutic candidates. Pharmacogenomics and personalized medicine offer insights into tailoring treatments based on genetic profiles, heralding a new era of individualized care. Blockchain technology, meanwhile, is revolutionizing the pharmaceutical supply chain by enhancing security, transparency, and traceability.

Advances, such as nanotechnology in drug delivery and 3D printing in pharmaceuticals, are redefining drug formulation and administration, enabling the development of precise, patient-specific solutions. The rise of telepharmacy and remote patient monitoring is breaking barriers to accessibility, making healthcare more inclusive. Pharmaceutical data analytics and digital health platforms are optimizing medication management, ensuring better outcomes for patients.

Regulatory technology (RegTech) is streamlining compliance in an increasingly complex regulatory landscape, while pharmacy automation and robotics are enhancing operational efficiency. Immunotherapy and biopharmaceuticals represent the cutting edge of therapeutic innovation, offering hope for previously untreatable conditions. Finally, pharmacy education technologies are equipping the next generation of professionals to excel in a rapidly evolving industry.

This book aims to serve as a foundational resource for students, researchers, and professionals who are eager to embrace these advancements and harness their potential. By exploring these topics in depth, we hope to inspire innovation and contribute to the continued growth of the pharmacy profession.

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INTRODUCTION

The pharmaceutical field has always been a dynamic and evolving discipline, responding to the ever-changing challenges of healthcare. In recent years, technological advancements have dramatically reshaped the landscape, bringing innovations that were once considered science fiction into everyday practice. This transformation not only holds the promise of improved patient outcomes but also challenges us to rethink the way pharmacy is practiced, researched, and taught.

Technical Advances in Pharmacy: An Overview is a timely and invaluable resource that captures the essence of this revolution. From artificial intelligence and blockchain technology to nanotechnology and 3D printing, this book provides a detailed exploration of the tools and innovations driving change. It highlights the shift towards personalized medicine, where treatments are tailored to individual genetic profiles, and emphasizes the importance of secure, transparent supply chains facilitated by blockchain technology.

This book also addresses critical advancements in patient care through telepharmacy and remote patient monitoring, ensuring accessibility to underserved populations. The integration of pharmaceutical data analytics and digital health platforms into daily practice demonstrates the potential for technology to optimize medication management and improve healthcare delivery.

Equally significant are the insights into regulatory technology (RegTech), automation, and robotics, which ensure compliance and operational efficiency in a highly regulated industry. The exploration of immunotherapy and biopharmaceuticals underscores the transformative potential of biological innovations in treating complex diseases. Additionally, the discussion on pharmacy education technologies is particularly relevant as we prepare future pharmacists to navigate a technology-driven world.

This book is an essential read for anyone involved in pharmacy—students, educators, researchers, and practitioners alike. It not only informs but also inspires readers to embrace these advancements and explore their potential to transform the practice of pharmacy. As we stand at the intersection of tradition and innovation, works like this provide the knowledge and perspective necessary to shape the future of the profession.

I commend the authors for their efforts in compiling such a comprehensive and forward-looking resource. I hope that this book will ignite curiosity, foster innovation, and contribute meaningfully to the advancement of pharmacy and healthcare.

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CHAPTER 1

Artificial Intelligence (AI) and Drug Discovery**Deenanath Jhade¹, Steward Mudenda² and Neeraj Sharma^{3,*}**¹ *St. Wilfred's Institute of Pharmacy, University of Mumbai, Mumbai, Maharashtra, India*² *Department of Pharmacy, University of Zambia, Lusaka, Zambia*³ *School of Pharmacy, IPS Academy, Indore, Madhya Pradesh, India*

Abstract: A potent tool that leverages human knowledge to solve complicated problems efficiently is artificial intelligence (AI). Drug research, pharmaceutical dosage formulation, and testing are at a turning point because of remarkable developments in AI and machine learning. Through the use of AI algorithms that examine vast amounts of biological data, such as proteomics and genomics, researchers can identify disease-associated targets and predict how they will interact with possible therapeutic options. This enables a more effective and precise approach to drug discovery, which in turn raises the possibility of drug approval. AI may also help reduce development expenses by streamlining research and development procedures. In addition to aiding in trial design, machine learning algorithms can predict the pharmacokinetics and toxicity of potential drugs. By prioritizing and optimizing the lead compounds, this capacity reduces the need for expensive and time-consuming animal testing. AI algorithms that evaluate actual patient data can support personalized medical strategies and improve patient adherence and treatment outcomes. This comprehensive overview examines the application of AI in drug discovery, dosage form design for drug delivery, process optimization, testing, and pharmacokinetics/pharmacodynamics (PK/PD) research. This chapter highlights the advantages and disadvantages of certain AI-based techniques used in pharmaceutical technologies. However, the pharmaceutical industry's ongoing investment and research present intriguing opportunities to improve patient care and drug development.

Keywords: Artificial intelligence (AI), Dosage form testing, Drug discovery, Machine learning, Pharmacodynamics, Pharmacokinetics, Physiologically-based pharmacokinetic (PBPK), Quantitative structure-activity relationship (QSAR).

INTRODUCTION

Artificial Intelligence (AI) refers to the simulation of human intelligence using computer systems to perform tasks, such as learning, reasoning, problem-solving, and decision-making. In healthcare, AI encompasses a wide range of applications,

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from diagnostic tools to usage planning and from patient management to pharmaceutical research. The use of AI has expanded significantly, driven by advancements in machine learning, big data analytics, and computational power [1, 2]. AI can be used to analyze vast datasets, identify patterns, and provide actionable insights, making it an invaluable tool for addressing complex healthcare challenges. Its scope in healthcare extends beyond diagnostics and imaging, delving into areas, such as drug discovery, personalized medicine, and advanced drug delivery systems, where it aids in designing efficient, patient-centric solutions [3 - 5].

Overview of Drug Delivery Systems and Challenges in Discovery and Development

Despite significant advancements, the discovery and development of novel drug delivery systems remains fraught with numerous challenges. One of the primary obstacles lies in the complexity of the formulation design. Designing an effective drug delivery system requires understanding and predicting the interactions between drugs, polymers, and other excipients. These interactions are influenced by multiple variables, including chemical composition, concentration, and environmental conditions, making them a multifactorial problem. This process often requires extensive experimentation, trial and error, and iterative refinement, which can be resource-intensive and time-consuming [6 - 8].

Another major challenge is the high cost and time-consuming nature of the development process. Research, development, and testing of new drug delivery systems require significant financial and temporal investment. From the initial conceptualization to preclinical and clinical trials, each phase presents a high risk of failure. This not only delays the availability of innovative therapies but also poses financial risks to pharmaceutical companies, potentially discouraging investment in novel delivery technologies.

Biological variability adds another complexity to drug delivery. Human physiology is inherently variable, with differences in enzyme levels, metabolic rates, and disease states that influence drug efficacy. For example, a formulation that works well in one individual may not achieve the same therapeutic effect owing to differences in absorption, distribution, metabolism, or excretion. This variability complicates the development of universally effective drug delivery systems, underscoring the need for personalized approaches to treatment.

Additionally, regulatory hurdles impede progress in this field. New drug delivery systems must meet stringent safety and efficacy standards set by regulatory agencies before reaching the market. The approval process often involves exhaus-

tive documentation, rigorous testing, and compliance with numerous guidelines, which can delay innovation and increase cost.

These challenges underscore the urgent need for innovative tools and methodologies to streamline the discovery process, optimize formulations, and predict outcomes more effectively. Integrating technologies, such as artificial intelligence, offers promising avenues to address these obstacles, thereby transforming the landscape of drug delivery research and development [9, 10].

Role of AI in Transforming Traditional Drug Delivery Research

Drug delivery systems are intended to transport therapeutics to their site of action in the body, enhance efficacy, and minimize side effects. Traditional approaches, such as tablets or injections, often suffer from limitations, such as poor bioavailability, systemic toxicity, and lack of targeted delivery. Modern approaches, including nanoparticles, liposomes, and transdermal patches, aim to overcome these issues by improving the controlled release, stability, and targeting mechanisms.

AI is revolutionizing traditional drug delivery research by offering powerful tools to address these challenges. Machine learning algorithms, for instance, can examine large datasets of drug properties, excipient combinations, and biological interactions to identify optimal formulations. Predictive representations can simulate drug release kinetics, bioavailability, and pharmacokinetics, significantly reducing the need for extensive *in-vitro* and *in-vivo* testing [11].

In addition, AI enables the design of personalized drug delivery systems by integrating patient-specific data, such as genetic information and disease profiles, to tailor treatment. AI-powered *in-silico* models facilitate virtual screening and rapid prototyping, thereby accelerating the development of innovative delivery platforms. Furthermore, AI-driven automation enhances precision in manufacturing and quality control, ensuring consistency in the delivery of drugs.

By influencing AI, investigators can overcome traditional bottlenecks, reduce costs, and enhance the accuracy of drug delivery systems, ultimately improving patient outcomes. This transformative potential highlights the importance of integrating AI into the drug discovery pipeline [1, 12].

CHAPTER 2

Pharmacogenomics: A New Paradigm in Personalized Medicine

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Abstract: Background: Pharmacogenomics deals with the study of genes, including their origin, effects, and constituents, in order to determine how they affect both morphology and system biology.

Objectives: Conventional dosage forms are typically available in a “one size fits all” manner, which may not be suitable for every individual. Pharmacogenomics focuses on understanding how genomic variations influence a person’s response to medication, with the aim of tailoring therapies to achieve optimal efficacy and safety.

Methodology: Various omic tools, such as proteomics, genomics, and metabolomics, are employed to discover biomarkers and optimize drug development. These approaches enable personalized therapeutic strategies by integrating molecular-level insights into clinical practice.

Conclusion: The applications of pharmacogenomic approaches can help pharmacologists to identify specific markers for improved clinical diagnosis and individualized dose design. This personalized framework enhances therapeutic outcomes and contributes to a better quality of life.

Keywords: Dose Design, Omics, Personalized Medicines, Pharmacogenomics.

INTRODUCTION

In biomedical science, pharmacology is the study of the effects of drugs on the living system. It encompasses several branches aimed at understanding drug actions and developing appropriate dosage forms for diverse populations. However, standardized and optimized doses fail to suit some individuals or a particular race. Variations in epidemiological background, environmental factors, or genetic constitutions further contribute to differences in drug responses across individuals. Prior to the advent of modern omic tools, pharmacology was primarily classified into two major branches:

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Pharmacokinetics (PK): It describes what the body does to a drug. It focuses on the movement of the drug through the body *via* the processes of absorption, distribution, metabolism, and excretion. This process generally refers to ADME.

Pharmacodynamics (PD): This explains what the drug does to the body, examining the biochemical and physiological responses resulting from drug-receptor and drug-enzyme interactions. These stimulate or suppress specific biological pathways to produce the desired therapeutic effect. It also considers how these mechanisms prevent adverse or unwanted effects by regulating drug action and metabolite activity [1].

In advanced medical science, the Human Genome Project, initiated in the late 20th century, marked a breakthrough in identifying target genes associated with life-threatening diseases such as cancer and autoimmune disorders. This field of study is known as Genomics. Building on this foundation, researchers have expanded into examining detailed interactions between genes, proteins, metabolites, and drugs through the use of omic tools, leading to a paradigm shift in drug discovery.

Omic tools are advanced computational and analytical technologies enabling the large-scale study of biological molecules, providing comprehensive insights into the composition, activities, and dynamics of a whole organism or a specific biological system. These tools are categorized by the system's biology and the molecular entities they investigate.

The term Omics is a collective concept where the suffix “ome” denotes a specific target to be studied, such as a complete set of genes, proteins, or metabolic biomolecules. Furthermore, the term “omics” is added to address the field of research related to specific biological targets, including genomics, transcriptomics, proteomics, and metabolomics.

Omic studies rely on analytical techniques and computational analytics to extract meaningful insights from large-scale, pre-existing biological datasets. By integrating omic datasets with Artificial Intelligence (AI) and Machine Learning (ML), these provide useful information about entire molecular systems to overcome data complexity and heterogeneity, empowering breakthroughs in drug discovery, biomarker identification, and therapeutic innovation. Omic tools can be divided into the following types-

Proteomics- focuses on studying the structure and function of proteins, which reveals drug targets and protein interactions essential for understanding disease mechanisms.

Metabolomics- decodes small molecular metabolites involved in physiological and pathological states, offering insight into drug metabolism and disease mechanisms through advanced tools.

Pharmacogenomics- Pharmacogenomics is an emerging branch of pharmacology that investigates how an individual's genetic makeup influences their response to prescribed medications. It combines genomics (the study of genes and their functions) and pharmacology (the science of drugs). This research can develop safe and effective drugs according to the genetic constituents of each individual for targeted medication.

The terms pharmacogenomics and pharmacogenetics are often used interchangeably; however, there is a significant difference in their scope. Pharmacogenetics focuses on the impact of a specific single gene on an individual's response to a drug. In contrast, pharmacogenomics investigates the effect of groups of genes or the entire genome on drug response and interactive biological pathways.

Both approaches are used to identify genetic variants, biomarkers, and drug-metabolizing enzymes or proteins that affect therapeutic outcome. These techniques enable the detailed analysis of DNA and RNA to uncover the molecular cause of disease and determine an appropriate treatment strategy. Currently, oncology and immunology are key areas where pharmacogenetics and pharmacogenomics are widely used to develop targeted therapy. As emerging pillars of personalized medicine, these fields integrate genetic, environmental, and lifestyle factors to optimize drug selection and dosing.

The human genome comprises approximately three billion bases, and although people share the majority of this sequence, even minor variations contribute significantly to individual differences. As pharmacogenetics explores how a gene influences drug response, the field has expanded with the introduction of pharmacogenomics, an omics discipline applied in the clinical sector. It targets identifying the genetic variations, particularly single-nucleotide polymorphisms of DNA, responsible for disease susceptibility, variability in drug absorption, which can lead to drug toxicity. This ensures the personalization of therapies tailored to suit the unique genetic constitution of an individual, thereby enhancing therapeutic efficacy while reducing adverse drug reactions and ultimately improving healthcare outcomes.

IMPACT OF PHARMACOGENOMICS ON SYSTEM BIOLOGY

Several factors, such as age, gender, metabolic efficacy, and environmental conditions, significantly influence the ADME of drugs, which in turn impacts the

CHAPTER 3

Blockchain in Pharmaceutical Supply Chain**Shweta Bhandari^{1,*}, Sambhav Lodha² and Vishal Garg³**¹ *Department of Pharmacy, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India*² *Faculty of Pharmacy, Bhagwant University, Ajmer, India*³ *Faculty of Pharmacy, Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, India*

Abstract: Blockchain technology has emerged as a potential solution to enhance the supply chain management in various industries, including the pharmaceutical sector. The blockchain is an electronic ledger, or a list of records, that is connected by cryptography and holds data that is made up of a block's header and the block itself. Throughout this procedure, these two elements together form a node in the chain that holds details about the other block's address and the current block. The ordered connection of nodes in a blockchain creates a data structure. As a digital data documentation method, this technology was created in 1991. However, in the early stages, this technology was hardly ever deployed or utilized at all. The rise of Bitcoin in 2009, however, abruptly brought it to greater attention. Enhancing the use of blockchain technology, a digital currency platform developed by Satoshi Nakamoto improved the application of blockchain technology. The block's hash component ensures its security feature by acting as a digital fingerprint. Every block has a different method for delivering encrypted data and security. Three key tenets of blockchain technology are immutability, transparency, and decentralization. By utilizing blockchain technology, pharmaceutical companies can improve transparency, traceability, and security throughout the supply chain process. With blockchain, the complete lifecycle of pharmaceutical products can be tracked, ensuring that the drugs are genuine and not counterfeit. Additionally, blockchain can help streamline the transaction process, enabling faster and more efficient supply chain operations. This can ultimately benefit patients by reducing the risk of receiving counterfeit or substandard medications and ensuring the integrity and safety of pharmaceutical products. Furthermore, the use of blockchain technology in clinical trials can revolutionize the research and development process. Blockchain technology can provide a decentralized and secure repository for storing patient data, ensuring its confidentiality and integrity. Overall, the implementation of blockchain technology in pharmaceutical supply chains can have a profound impact on patient safety, efficient supply chain management, and the advancement of healthcare research and innovation. The integration of blockchain technology in the pharmaceutical supply chain can address key challenges such as counterfeit drugs, inefficient inventory management,

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and a lack of transparency. Due to the extreme disarray and fragmentation of the pharmaceutical business, the existence of numerous suppliers in the supply chain exacerbates the problem with drug quality. The inferred benefits of blockchain technology for improving store network administration involve reducing or eliminating errors and deception, lowering delays caused by printed materials, improving inventory control, identifying problems earlier, cutting down on dispatch costs, and increasing customer and partner trust. Blockchain innovation may also contribute to better inventory network execution through the central mechanism of using smart contracts to automate processes and reduce expenses. By leveraging the decentralized and transparent nature of blockchain, pharmaceutical companies can create a secure and trustworthy system for tracking the movement of drugs from manufacture to endpoints. Despite the fact that blockchain technology is still in its early stages, there have been advancements in application in daily life, primarily in the pharmaceutical and financial industries.

Keywords: Blockchain technology, Complex supply chain, Counterfeit drugs, Cryptography, Digital ledger, Pharmaceutical sector, Revolutionizing clinical trials, Supply chain management.

INTRODUCTION

Technology-driven solutions find use in the pharmaceutical supply chain. Blockchain technology can be used for automation and administration of the pharmaceutical cold chain. \$200 billion is spent annually on grey, substandard, counterfeit, and fraudulent pharmaceuticals in the global pharmaceutical business [1]. Research has shown that a wide range of goods, including biological gadgets, pharmaceuticals, agricultural products, and health aids, are being counterfeited in different nations. This indicates that the entire drug supply chain is vulnerable to these kinds of crimes [2]. The healthcare sector is also prepared for advancements in supply chain management. This viewpoint aims to enhance the understanding of and prospects for blockchain applications in supply chains centered on health and pharmaceuticals [3]. Among the pharmaceutical markets with the fastest growth in recent years is India. Between 2005 and 2018, the pharmaceutical and agro-based industries experienced annual growth of 18.4%. Over the same time period, the generic drug industry grew at an even quicker rate of 23% per year and accounted for 20% of global ports by volume. On the other hand, although India appears to be on a solid economic trajectory, there appears to be a significant deficiency in the use of technology in supply chain management to prevent the production of counterfeit goods [4]. Indian pharmaceutical companies are dealing with a unique combination of issues that are putting a lot of pressure on them to change and provide solutions based on the cutting-edge technology. To meet the needs of its growing population, India has to build enormous medical infrastructure and medical digs. Given that they offer safe, quick, easy, organised,

secure, and convenient solutions, current technological solutions have the potential to significantly contribute to the transformation of India's medical and healthcare industries.

Blockchain employs a decentralized, transparent, controllable, and secure approach to operate on the fundamental phenomena of non-repetition and symmetry of objects. When the supply and demand for pharmaceuticals are properly managed, the blockchain idea in the pharmaceutical supply chain can be used to identify counterfeit medications. Pharmaceutical businesses will be able to regulate counterfeit and unregistered medications as a result. Fake and unlicensed medications pose a serious risk to human life because they do not offer any medical relief and can have a number of negative side effects that can seriously impair health or even result in death in certain situations.

Global pharmaceutical firms need a safe and regulated medical supply chain to prevent harm to people's lives. Blockchain technology can help with this by enabling secure and regulated methods for the distribution of life-saving medications. The integration of sensors and a linked business supply chain environment is part of the blockchain deployment for clinical communities to offer prompt, secure, and safe solutions. Real-time data sharing for drug traceability and supply chain security is provided by numerous cloud-based technologies. Granting patients direct access and allowing them to share their information. With the help of this type of information sharing, several experts can offer their opinions and the optimum medication for the condition can be identified, which will benefit both the patient and the pharmaceutical company.

The term “blockchain” refers to an electronic ledger, or a list of records, which is connected by cryptography and holds data composed of a block's header and the block itself. Throughout this procedure, these two elements together form a node in the chain that holds details about the other block's address and the current block. The ordered connection of nodes in a blockchain creates a data structure. As a digital data documentation method, this technology was created in 1991. However, in the early stages, this technology was hardly ever deployed or utilized at all. The rise of Bitcoin in 2009 [5], however, abruptly brought it to greater attention. Enhancing the use of blockchain technology, a digital currency platform developed by Satoshi Nakamoto [6] improved the application of blockchain technology. The block's hash component ensures its security feature by acting as a digital fingerprint. Every block has a different method for delivering encrypted data and security. Consider a shared ledger that is available to several people at once, akin to a massive spreadsheet. The network records and verifies every modification, making it transparent and impervious to tampering. This is what blockchain is all about. This ledger enables the monitoring of

CHAPTER 4

Critical Assessment of Optimization Parameters for Transfersomes-based Transdermal Drug Delivery System

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Abstract: Transdermal delivery systems have attracted a lot of attention recently due to their advantages over traditional delivery methods. They are non-invasive, self-administered delivery devices that can increase patient adherence and offer a regulated release of therapeutic substances. The barrier-like function of the skin layer is the biggest difficulty for transdermal delivery methods. Ionized substances and molecules with large molecular weights are unable to penetrate the skin; as a result, this route can only be used to provide a small number of medications. The potential solution to this issue is to encapsulate the medications in transfersomes. In contrast to traditional liposomes, they feature a bi-layered structure that makes it easier to encapsulate drugs that are hydrophilic, lipophilic, and amphiphilic. The elastic nature of transfersomes increases their ability to deform and squeeze through tiny pores that are much smaller than their own size. The factors associated with the formulation of transfersomes, including the concentration of ingredients and method of preparation, significantly affect the quality of the formulation, thereby altering the pattern of drug release and bioavailability of poorly soluble drugs. The transfersome formulation can be optimized using various factorial designs by modulating dependent and independent variables. The summary of the effect of optimization parameters on transfersome formulation is presented in this paper, along with the various factors affecting the characteristics of transfersomes. These factors include the type and concentration of surfactants, the lipid composition, and the method of encapsulation used. By carefully selecting and adjusting these parameters, researchers can enhance the stability, permeability, and overall effectiveness of transfersomes for improved drug delivery.

Keywords: Encapsulation, Skin, Transdermal, Transfersomes, Vesicular bilayer.

INTRODUCTION

The history of pharmaceutical science has witnessed that most of the time, it is impossible to provide an effective therapy, due to a variety of factors, including

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the occurrence of hepatic first-pass metabolism, unfavorable side effects, the rejection of invasive treatments, and low patient compliance [1]. To solve these issues, various medication delivery systems have been developed, including Transdermal delivery systems, which are a viable strategy because they are minimally invasive and have no first-pass effects. These systems allow for a steady release of medication through the skin, enhancing therapeutic outcomes while minimizing potential side effects. Furthermore, transdermal delivery can improve patient compliance, as it often results in less frequent dosing compared to traditional oral medications. However, it is necessary to address the skin's barrier function, which hinders or prohibits the Transdermal distribution of therapeutic substances [2, 3].

The aforementioned issue has been solved by nanoencapsulation employing a lipid-based vesicular system.

Three possible mechanisms exist for how a lipid-based vesicular system can speed up drug delivery through the skin: adsorption to the skin surface followed by direct drug delivery from vesicles to the skin; fusion with the stratum corneum's lipid matrix, which increases drug partitioning into the skin; and lipid exchange between the lipid-based vesicular system membrane and cell membrane, which speeds up drug delivery across the membrane [4, 5]. Conventional lipid-based vesicular systems also have drawbacks, such as inadequate hydrophilic drug encapsulation efficacy, an unstable membrane that causes leaky behavior, and a short half-life [6 - 8]. These vesicles include niosomes, sphingosomes, bilosomes, chitosomes, transfersomes, ethosomes, and invasomes.

The discovery of niosomes dates back to the early 1970s. They are made up of cholesterol, nonionic surfactants, and ionic amphiphiles. Cholesterol makes the vesicular bilayer stiff, but nonionic surfactants make niosomes bigger and more effective at encasing molecules [9]. Additionally, several ionic amphiphiles are employed in niosomes to improve their stability, efficacy, and efficiency for trapping [10].

In the 1990s, Cevc *et al.* introduced transfersomes, a brand-new class of carrier system. Transfersomes are made of phospholipids and edge activator, a membrane-softening substance (such as Tween 80, Span 80, and sodium cholate) that promotes the transfersomes' ultra-deformable nature. Transfersomes can alter the flexibility of their membranes and spontaneously flow through the skin pores when they get close to the skin pores [11]. Additionally, transferomes are incredibly flexible; they can easily pass through even the narrowest pores [12]. These self-optimizing, highly deformable lipid aggregates were effective for the transcutaneous administration of peptides and proteins [13].

Researchers who are interested in or working on elastic vesicle-based transdermal drug delivery will find it helpful to have a working knowledge of the term, the underlying idea, preparation and characterization techniques, as well as factors affecting the properties of the first generation of elastic vesicles (transfersomes). With a focus on their latest applications in the transdermal administration of pharmaceuticals, this chapter provides an overview of the mechanisms of action, various preparations, characterization methods, and factors determining the properties of transfersomes in the current review.

TRANSFERSOMES

An edge activator and at least one inner aqueous compartment enclosed by a lipid bilayer are features of transfersomes, which are vesicular carrier systems [11]. These ultra-deformable vesicles with an aqueous core and a lipid bilayer on top are capable of self-optimizing and self-regulating [14]. Transfersomes are elastic by nature and may, therefore, deform and squeeze themselves as complete vesicles through microscopic holes or skin constrictions that are substantially smaller than the vesicle size without noticeable loss [15, 16]. The modified liposomal vesicular system (transfersomes) is built of the phospholipid component and single-chain surfactant as an edge activator, in contrast to normal liposomes, which are constituted of natural (such as egg phosphatidylcholine—EPC and soybean phosphatidylcholine—SPC) or synthetic (such as dimyristoyl phosphatidylcholine—DMPC, dipalmitoyl phosphate). When combined in the right proportion with the right lipid, Edge Activators (EAs) perform exceptionally well as membrane-destabilizing agents to increase the deformability of vesicle membranes. This mixture allows the transfersomes to become deformable and ultra-flexible, which leads to a higher permeation capability [17, 18]. Because of this, transfersomes are able to penetrate pores that are much smaller than their own diameters and circumvent the main shortcomings of ordinary liposomes.

Furthermore, even after passing through the narrower pores, the transfersomes kept their diameters against fragmentation. The transferosomal formulation has improved performance over traditional liposomes as a result of the use of EAs [17, 18]. The EAs utilized in transferosomal formulations can help hydrophobic medicines become soluble, improving the formulations' ability to entrap pharmaceuticals [19 - 21]. Additionally, the skin lipids may be fluidized and solubilized by the EAs, improving skin penetration [22, 23]. The type and concentration of EAs used in skin permeations affect the impact. One of the numerous distinct substances that function as edge activators and penetration enhancers is surfactant [24]. They are recognized as being amphiphilic compounds with a hydrophilic head group attached to a lipophilic alkyl chain [25]. Anionic surfactants are typically more effective at improving skin

CHAPTER 5

Telepharmacy and Remote Patient Monitoring

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Abstract: Telepharmacy and remote patient monitoring (RPM) are emerging technologies transforming healthcare delivery by expanding access to services and improving patient care. Telepharmacy utilizes telecommunication technologies to provide pharmacist expertise and medication services to patients remotely, addressing geographical and mobility limitations. RPM allows for continuous patient monitoring, improving chronic disease management and enabling early intervention for potential health problems. This book chapter explores these advancements in telepharmacy and RPM. It discusses how telepharmacy bridges gaps in access to pharmaceutical services, particularly in underserved areas. It explores how RPM enhances healthcare delivery by enabling remote patient monitoring and chronic disease management. The chapter also highlights the potential of telepharmacy and RPM in rural healthcare settings. Finally, it addresses ethical and legal considerations surrounding these evolving practices.

Keywords: Telehealth, Telepharmacy, Remote patient monitoring.

INTRODUCTION

The growing popularity of telehealth includes the capability to oversee specific facets of a patient's well-being directly from their own home. The goal of telemonitoring, which dates back to the 1990s, has always been to make patient disease management easier at home [1]. Telepharmacy and remote patient monitoring are two significant developments in this field. While telepharmacy is the practice of providing pharmacy services from a distance by connecting patients and pharmacists using telecommunications technology, remote patient monitoring goes beyond the conventional hospital environment, allowing patients to continuously check their health data from the comfort of their own homes. These technology developments help to effectively manage a variety of medical disorders in addition to improving access to healthcare services [2]. Together, telepharmacy and remote patient monitoring allow healthcare professionals to

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oversee both short-term and long-term health conditions, while also reducing the financial burden and health risks associated with patient travel.

Telepharmacy holds numerous applications of considerable ethical value, especially its commitment to providing patients who may not otherwise have access to adequate treatment the necessary pharmacological assistance. Adopting telepharmacy can help address the scarcity of pharmacists and contribute to providing sufficient pharmaceutical support in underprivileged areas [3]. Remote patient monitoring allows healthcare professionals to oversee both short-term and long-term health conditions, while also reducing the financial burden and health risks associated with patient travel. As telepharmacy addresses medication accessibility and adherence, remote patient monitoring extends its impact by enabling real-time tracking of health parameters, ensuring integrated care delivery.

Systems for remote patient monitoring are intended to collect various physiological data from patients [4]. The most often collected data are electrocardiograms (ECGs), electroencephalograms (EEGs), heart rates and respiration rates, blood oxygen content or pulse oximetry, nervous system signals, blood pressure, skin and body temperatures, and blood glucose levels.

In the ever-evolving landscape of modern healthcare, the integration of telehealth and remote patient monitoring stands as a pivotal step in the quest for enhanced accessibility and personalized care. The advancement of these technologies has not only revolutionized the conventional healthcare paradigm but has also made them an essential element in maintaining continuity and effectiveness in patient care [5]. This chapter explores the development of telehealth and remote patient monitoring across time, following its inception from early telemedicine trials to the complex, networked systems of today. It looks at the developments in technology, such as wearables, IoT sensors, and artificial intelligence, which have propelled this transition.

TELEPHARMACY: BRIDGING GAPS IN ACCESS TO PHARMACEUTICAL SERVICES

In today's healthcare environment, telepharmacy is a dynamic solution that successfully bridges gaps in drug management and addresses issues with adherence and availability. With the use of technology, this creative method connects pharmacists to patients remotely, allowing for advice, evaluations, and consultations on medications. Telepharmacy is a lifesaver in areas where people may not have easy physical access to pharmacies, as it ensures that individuals receive accurate and timely drug information. Furthermore, by providing tailored treatments, telepharmacy improves drug adherence since pharmacists may visit

patients in their homes and provide assistance [6]. A complete and well-coordinated approach to medication management is fostered by the increased simplification of provider collaboration through the integration of electronic health records and secure communication platforms. Telepharmacy is emerging as a game-changing technology as the healthcare landscape continues to change.

Telepharmacy has multiple economic benefits. According to reports, establishing a new pharmacy store is much more expensive than the cost involved in recruiting pharmacy technicians for telepharmacy and purchasing the necessary equipment. A single skilled pharmacist can provide services to multiple sites, which minimizes costs compared to hiring additional pharmacists for rural sites and rising pay scales for pharmacists [7]. A telepharmacy model aimed at low-income patients found that over 60% of patients would have difficulty affording their medication without the telepharmacy model.

A study conducted by Ibrahim *et al.* (2022) assessing the impact of telepharmacy in the management of hypertension revealed that this intervention may have a long-lasting impact on the blood pressure of individuals for up to a year [8]. Additionally, this intervention can enhance pharmacists' capacity to recognize and avoid drug-related issues in community settings [9].

A study by Iftinan *et al.* (2023) [10] demonstrated that telepharmacy is a valuable tool for enhancing clinical outcomes, promoting patient adherence to therapy, and minimizing hospitalization and patient visits. However, telepharmacy has certain drawbacks related to security and privacy, as well as the underutilization of pharmacist intervention. Nonetheless, people with diabetes mellitus may benefit greatly from telepharmacy's pharmaceutical services.

Bridging gaps in medication management involves navigating a myriad of regulations, standards, and guidelines set forth by health authorities and regulatory bodies. One major issue is the absence of established methods in various areas, which can result in variations in medicine usage and perhaps gaps in patient care. Aligning developing technologies with current regulatory frameworks is also a difficulty due to their integration, including telehealth platforms and electronic health records. It is critical to strike a balance between encouraging innovation and guaranteeing legal compliance. Moreover, it is getting harder to maintain seamless drug management due to the growing frequency of polypharmacy and the complexity of treatment regimens. To develop a cohesive regulatory framework that supports patient-centered care, encourages interoperability, and improves the general safety and effectiveness of drug management, healthcare stakeholders must work together to solve these issues.

CHAPTER 6

3D Printing in Pharmaceuticals

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Abstract: 3D printing, or additive manufacturing, has gained significant attention in the pharmaceutical sector for its potential to revolutionize drug development, manufacturing, and delivery. This review explores the principles of 3D printing, the diverse technologies adapted for pharmaceutical applications, and their transformative impact on personalized medicine, drug delivery systems, and rapid prototyping. Challenges, including material selection, regulatory hurdles, and ethical considerations, are also discussed alongside future directions for research and industrial implementation. By integrating 3D printing with emerging technologies, such as artificial intelligence, this field holds immense promise for creating innovative, patient-centered healthcare solutions.

Keywords: Drug Delivery Systems, Ethical consideration, Healthcare solutions, Patient-centered, 3D printing.

INTRODUCTION

3D printing, also known as additive manufacturing, represents a transformative technology that constructs objects layer by layer based on a digital blueprint. Since its inception in the 1980s, the technology has evolved from being a niche prototyping tool to a mainstream manufacturing method across industries, such as aerospace, automotive, and healthcare [1]. In the pharmaceutical sector, 3D printing has emerged as a groundbreaking approach with the potential to revolutionize drug development, production, and delivery [2].

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The pharmaceutical industry is heavily reliant on precision, consistency, and innovation. Traditional drug manufacturing processes, while efficient for large-scale production, often fall short in addressing the need for personalized medicine. Personalized medicine aims to tailor treatment regimens to individual patients based on their genetic profiles, disease states, and physiological needs. Achieving this level of customization is challenging using conventional methods, which are designed for mass production rather than individual specificity. Here, 3D printing offers unparalleled advantages by enabling the production of highly customized dosage forms and drug delivery systems [3, 4].

One of the most significant milestones in pharmaceutical 3D printing was the FDA approval of Spritam®, a levetiracetam tablet for epilepsy, in 2015. Manufactured by Aprelia Pharmaceuticals using their proprietary ZipDose® technology, Spritam® demonstrated how 3D printing could produce fast-dissolving, high-dose medications tailored to patients' needs. This landmark approval highlighted the potential of 3D printing to redefine drug manufacturing paradigms, sparking widespread interest in its applications [1, 5].

The advantages of 3D printing in pharmaceuticals extend beyond customization. The technology allows for the fabrication of complex geometries and multi-functional structures that are unattainable through traditional methods. This capability enables the development of advanced drug delivery systems, such as sustained-release tablets, multi-layered polypills, and microneedle patches. Moreover, 3D printing facilitates the incorporation of multiple active pharmaceutical ingredients (APIs) with varying release profiles into a single dosage form, thereby improving patient compliance and therapeutic outcomes [6, 7].

Another critical aspect of 3D printing is its ability to streamline the drug development process. By enabling rapid prototyping and testing, 3D printing significantly reduces the time and cost associated with bringing a new drug to market. Researchers can quickly fabricate and evaluate different formulations, optimizing them for performance and patient acceptability. This accelerates the iterative cycle of drug design, testing, and refinement [7, 8].

In addition to enhancing drug formulation and delivery, 3D printing has shown promise in producing orphan drugs and medications for rare diseases. These drugs often face challenges related to limited demand and high production costs, making traditional manufacturing economically unviable. With 3D printing, pharmaceutical companies can produce small batches of highly specialized drugs on demand, ensuring that patients with rare conditions have access to essential treatments.

However, the integration of 3D printing into pharmaceuticals is not without challenges. The selection of suitable materials—both active pharmaceutical ingredients and excipients—is a critical factor that influences the efficacy and safety of 3D-printed products. Ensuring uniformity in drug distribution, maintaining stability during the printing process, and meeting stringent regulatory standards are some of the technical hurdles that need to be addressed. Furthermore, the high initial investment in 3D printing equipment and the need for specialized expertise may limit its adoption in resource-constrained settings.

Despite these challenges, the potential of 3D printing to transform the pharmaceutical landscape is undeniable. As the technology continues to advance, it is expected to play a pivotal role in the development of personalized therapies, on-demand drug manufacturing, and innovative drug delivery systems. This review aims to provide a comprehensive overview of the principles, applications, and challenges of 3D printing in pharmaceuticals, offering insights into its current state and future prospects [1, 5, 8].

Principles and Technologies of 3D Printing

Overview of 3D Printing

3D printing, fundamentally an additive manufacturing process, involves the creation of three-dimensional objects by depositing materials layer by layer, guided by a digital model. This contrasts with subtractive manufacturing, where material is removed to form an object. In pharmaceuticals, the focus lies on precision, reproducibility, and the ability to incorporate active pharmaceutical ingredients (APIs) into complex geometries [9 - 11].

Technologies in Pharmaceutical 3D Printing

Fused Deposition Modeling (FDM)

Fused Deposition Modeling (FDM) is a widely used additive manufacturing technology that creates three-dimensional objects by depositing material layer by layer. Developed by Scott Crump in the late 1980s and commercialized by Stratasys Inc., FDM uses thermoplastic filaments, which are melted and extruded through a heated nozzle to form precise shapes. The material solidifies as it cools, bonding with previous layers to gradually build the desired object. This method is valued for its simplicity, cost-effectiveness, and suitability for prototyping and functional part production [12].

The process begins with designing a 3D model using Computer-Aided Design (CAD) software. The model is then sliced into thin horizontal layers using slicing

Pharmaceutical Data Analytics

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Abstract: The application of data analytics in healthcare has emerged as a revolutionary technology, enabling organizations to manage and analyze vast amounts of medical data efficiently. Big data provides a robust platform for healthcare institutions to convert raw information into meaningful insights, thereby enhancing service delivery, optimizing resources, and improving decision-making processes. The primary sources of big data in healthcare include hospital databases, patient medical records, diagnostic reports, and data generated by medical devices. By leveraging advanced data analytics, healthcare organizations can enhance their analytical capabilities, develop data-driven strategies, and gain valuable insights to improve operational, managerial, and strategic functions. Big data analytics significantly contributes to IT infrastructure by streamlining healthcare processes, enhancing patient outcomes, and supporting evidence-based decision-making. However, handling large-scale healthcare data presents significant challenges that necessitate high-performance computing solutions to ensure accurate and efficient analysis. The integration of biomedical and healthcare data with modern technologies has the potential to revolutionize medical therapies and personalized treatment approaches. The advancements in data science and machine learning have further strengthened these systems, facilitating real-time data collection from mobile and wireless healthcare devices connected via the internet. The emergence of smart medical devices has empowered healthcare professionals by providing comprehensive and sustainable analytical support. Healthcare organizations are continuously seeking innovative IT solutions that can consolidate their digital resources to enhance patient care, improve institutional performance, and develop new, data-driven business models. Through an in-depth analysis of big data applications, this study highlights how healthcare organizations can harness analytics to transform IT infrastructure and maximize business value. Despite the promising potential of big data in healthcare, certain limitations exist. One major challenge is the slow adoption of IT in the healthcare industry compared to other sectors, making case studies on successful implementations relatively scarce. Additionally, much of the available data originates from vendors, which may introduce bias as vendors typically highlight only their success stories. Future research should focus on collecting and analyzing primary data from diverse

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sources to provide a more comprehensive and unbiased perspective on the role of big data analytics in healthcare transformation.

Keywords: Computing, Data analytics, Health care, Information technology.

INTRODUCTION TO PHARMACEUTICAL DATA ANALYTICS

Overview of the Pharmaceutical Industry

The Pharmaceutical Industry is one of the most developed industries, which ranks fourth in terms of volume and thirteenth in terms of value. In India, the pharmaceutical industries have made tremendous progress in infrastructure, technicality, research and development, quality of medicines, production of bulk drugs, etc. Not only these, pharmaceutical industries have also grown in terms of supply and management. The majority of production worldwide comes from the U.S., Europe, and Japan, which collectively contribute 80% of the total global market. The Indian pharmaceutical industries alone contribute 10% of the global market. In world exports, pharmaceutical industries' products have grown in the past few years. The evolution of the pharmaceutical industry started in 1901 in Kolkata, where the first pharmaceutical industry in Bengal, Bengal Chemical and Pharmaceutical, began operations. After that, other industries, such as Alembic Chemicals, started in Vadodara [1]. The evolution of the Indian pharmaceutical industry has five phases to date, which are as follows:

- Phase I: This phase is an early phase where there were very few pharmaceutical industries and a lot of dominance by foreign industries.

- Phase II: This phase was under government control, where local companies had a devastating impact on society and welfare, leading to the Indian Patent Act of 1970, and drug prices also increased.
- Phase III: This phase is a development phase where rapid research and development of drugs and medicines occur.
- Phase IV: This is a growth phase that has led to the expansion of the market and the orientation of research.
- Phase V: This is the new phase, i.e., innovation and research, where new ideas and innovations lead to intellectual property rights.

The pharmaceutical industry is a heterogeneous mixture of large, medium, and small-scale industries. In 2007, there were 10,563 pharmaceutical industries in India, among which 8,174 are formulation units and 2,379 are manufacturing bulk drugs. The tremendous growth of the pharmaceutical industry is generating huge amounts of data that need to be analyzed. New guidelines are designed to

safeguard this data, which improves patient safety and makes the industry more economically developed. This led to the need for data analytics in the pharmaceutical industry [2].

IMPORTANCE OF DATA ANALYTICS IN PHARMA

Role of Data Analytics in Process Validation

Process validation is a process in the pharmaceutical industry that generates data throughout the design and manufacturing of a product to ensure that the process produces output of predetermined standards. Lacking it may cause great harm to patient safety and the economy of the industry. Therefore, data analytics and data integrity are critical points in the pharmaceutical industry. The FDA has issued new guidelines for data integrity and the safe handling of data. It has provided a centralized system to handle data used by software engineers, along with a blockchain system. Manipulation of data can be easily detected, and regulatory agencies can track the manipulated data alongside the original data. These enhance trust in pharmaceuticals by securing the intellectual property of individual companies and ensuring patient safety. Since pharmaceutical industries are required by regulatory bodies to manage large volumes of process and analytical data to demonstrate that their products are safe for patients, data analytics plays a crucial role in the pharmaceutical industry.

Role of Data Analytics in Operations

A large amount of data is generated daily through operations; however, most of this data remains unutilized and does not add any value. Therefore, it is important for the pharmaceutical industry to develop effective strategies for anchoring data using data analytics models. Industries should focus on a data analytics-driven culture to ensure that data is proactively generated and recorded [3].

Role of Data Analytics in Sales and Marketing

Marketing and sales managers in the pharmaceutical industry often face huge problems in handling large market and sales data. There is a lot of difficulty in recognizing sold-out products. Therefore, they need proper data mining tools to identify which sales and marketing managers can overlook the doctors visited by medical representatives, and to also set targets for these representatives [4].

The Role of Data Analytics in Hospital Pharmacy

Data analytics enhance the delivery of care in healthcare settings, improve medication adherence, and facilitate medication reconciliation. This entire process

CHAPTER 8

Digital Health Platforms for Medication Management

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Abstract: Many people take multiple prescribed and unprescribed medications, a practice known as polypharmacy, which can hinder medication adherence. Noncompliance with medication may reduce therapeutic benefits and increase the risk of morbidity and mortality. As a result, precise measurement and tracking of patient medication adherence are critical in both clinical practice and research. Medical management through digitalization—such as mobile health apps, electronic health records (EHRs), smartwatches, telehealth/telemedicine, and personalized medicine—is increasingly being adopted. Digital health platforms that utilize mobile applications integrate a variety of functionalities, including remote monitoring, patient engagement, data analytics, and communication tools, to enhance healthcare delivery. Patients can easily access personalized treatment, monitor their health metrics, and communicate with healthcare providers in real time *via* mobile apps. When combined with integrated EHRs, digital health platforms offer numerous benefits, such as prescription reminders, dosage tracking, adverse event monitoring, and seamless communication between patients and healthcare professionals. This abstract also highlights challenges such as interoperability, data security, user engagement, and equitable access to digital health technologies. Overall, it examines the importance of digital health platforms in enhancing medical management, highlighting their potential to improve patient outcomes, increase healthcare efficiency, and facilitate proactive healthcare delivery.

Keywords: Adherence, Application, Digital, EHealth, EHR, Electronic Health Records, Electronic Medical Records, Health platform, Management, MHealth, Mobile, Medication, mobile app, Patient, Physician, Pharmacy, Pharmaceuticals, Reminder, Smartphone app.

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BACKGROUND

Throughout history, medications have played a crucial role in curing and controlling the spread of illnesses, bacteria, and even viruses [1]. Medication, both prescribed and unprescribed, is widely used to treat acute and chronic health issues, as well as to maintain overall health [2, 3].

Given the increasing incidence of drug usage and polypharmacy, understanding and optimizing medication management is critical. Medication management is defined as “patient-centered care to maximize safe, effective, and appropriate drug therapy.” Medication management encompasses a range of activities designed to enhance clinical outcomes, including conducting medication reviews and health assessments, monitoring treatment plans and therapy efficacy and safety, providing education, and promoting self-management [4, 5].

INTRODUCTION (MEDICATION ADHERENCE)

Medication adherence is one of the most significant concerns in healthcare worldwide. Medication adherence, according to the World Health Organization (2003), is “the degree to which the person's behavior—taking medication, following a diet, and/or executing lifestyle changes—corresponds with the agreed-upon recommendations from a health care provider” [6].

Compliance refers to the extent to which a patient's behavior aligns with the prescriber's advice [7]. Medication persistence is defined as the time between the initiation of treatment and its discontinuation [8]. Medication adherence behavior can be defined as a combination of two concepts: adherence (taking prescribed drugs as directed) and persistence during the treatment period. This involves taking the proper dose at the appropriate time and for the indicated duration of time [6, 9].

When they do not do this, it is commonly referred to as “treatment nonadherence” or “treatment noncompliance,” with serious repercussions [10]. Noncompliance with the medication may result in extra hospital visits and, in certain situations, re-hospitalization. Noncompliance with correctly recommended medications may result in reduced therapeutic benefit and increased morbidity and mortality risk [10, 11].

Accurately measuring and tracking patient medication adherence is crucial in both clinical practice and research settings, yet it remains a significant challenge worldwide [12]. Medication adherence can be measured using a variety of approaches, including patient self-reports, pill counts, pharmacy refill records, drug metabolites or biomarker tests, and direct observed therapy (DOT) [13].

However, none of these techniques has been adopted as a standard measure of drug adherence across a variety of situations (Table 1) [9, 14].

Table 1. Medication adherence assessment.

Type of Assessment	Assessment Methods	Characteristics	Advantages	Disadvantages
Direct	Drug/metabolite level measurement	Drug/metabolite concentration measured	Accurate; Provides ingestion of the drug	Costly Invasive Inter-individual differences
Indirect	Pill Count	Missed doses numbers measured	Simple Mostly used in clinical trials	No evidence of ingested medication
-	Electronic databases	Medication possession ratio (MPR) Proportion of days covered (PDC)	Easy to use Inexpensive Non-invasive, patients are not aware that they are being monitored Especially specific to identify non-adherent patients	Evidence of the drug being dispensed but not ingested
-	Self-reported (questionnaires, visual analogue scales)	A value that is interpreted in regard to a pre-established cut-off point	Easy to use Inexpensive	Overestimate adherence Subjective, influenced by recall or reporting bias
-	Electronic monitoring systems	Overall percentage of doses taken Dosing regime	Objective Additional information on the degree of adherence One of the most accurate methods	The patient is aware of the evaluation No actual evidence that the medication is being ingested

MEDICATION MANAGEMENT

Digitalization, often referred to as digital health or digital healthcare, is a broad, interdisciplinary concept that integrates technology and healthcare. It combines software, technology, and services, including mobile health apps, electronic health records, electronic medical records, wearable devices, telehealth/telemedicine, and personalized medicine [15].

Taking drugs regularly and at the appropriate times might be difficult; hence, numerous tools/apps have been developed to help people remember their

Immunotherapy and Biopharmaceuticals

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Abstract: For thousands of years, plants have played a vital role in medicine, with an estimated 80% of the global population relying on herbal remedies for healthcare, particularly in regions with limited access to conventional pharmaceuticals. Among these medicinal plants, garlic (*Allium sativum* L.) has gained significant attention due to its potent bioactive compound allicin. Allicin is enzymatically produced when garlic is crushed, converting the precursor alliin into this sulfur-containing compound. It exhibits a broad spectrum of health-promoting properties, including antimicrobial, anticancer, antioxidant, and cardiovascular protective effects. Recent studies have also highlighted allicin's immunomodulatory potential, suggesting a possible role in immunotherapy, particularly in enhancing the immune system's ability to detect and combat disease. Immunotherapy, a cutting-edge approach in oncology, leverages the body's own immune system to target and eliminate cancer cells. It has become a major focus of global cancer research. For instance, a recent large-scale study compared neoadjuvant and adjuvant immunotherapy in perioperative cancer patients, underscoring the growing significance of immunotherapy in clinical settings. Despite allicin's therapeutic promise, especially in immunomodulation, several challenges hinder its broader application. These include a limited understanding of its precise mechanisms of action, instability during processing, and variability in yield depending on the extraction method. This chapter addresses these issues through a comprehensive bioprospecting approach that integrates molecular docking techniques to investigate allicin's interactions with bacterial proteins and drug resistance targets. Moreover, the study evaluates eco-friendly and efficient extraction techniques, including the use of green solvents and ultrasound-assisted extraction, to enhance allicin yield and stability. By combining innovative extraction methodologies with molecular and pharmacological insights, this chapter aims to promote the therapeutic application of allicin, particularly in the emerging field of immunotherapy, thereby contributing to the development of effective, natural, and sustainable biopharmaceuticals.

Keywords: Allicin, Antimicrobial, Biopharmaceuticals, Extraction methods, Immunotherapy.

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INTRODUCTION

For thousands of years, plants have served as a vital source of medicine, enhancing the quality of life for many cultures worldwide. According to the World Health Organization (WHO), 80% of the global population relies on plant-based alternative systems, including traditional herbal medicine, for some aspects of primary healthcare, particularly where access to pharmaceutical products is limited [1]. This longstanding reliance on plants in healthcare has given rise to the concept of phytopharmaceuticals, often referred to as phytotherapy.

This chapter presents an overview of the bioprospecting of allicin, a sulfur-containing volatile biopharmaceutical compound found in garlic (*Allium sativum* L.). Allicin, also known as diallyl thiosulfinate or S-allyl cysteine sulfoxide, is one of the primary bioactive organosulfur compounds synthesized in the *Allium* species. Notably, allicin constitutes about 70% (w/w) of the total thiosulfinate content in fresh garlic, representing approximately 0.4% of its fresh mass [2]. This colorless, oil-like substance is poorly soluble in water and does not exist in intact garlic cloves. Instead, it is produced when garlic is crushed, allowing the stable and odorless precursor, alliin (S-allyl-L-cysteine sulfoxide), to react with the enzyme alliinase (alliin lyase, EC 4.4.1.4), found in different compartments of the garlic clove [3]. This enzymatic reaction results in the formation of allicin, which quickly metabolizes into various secondary compounds, such as dithiins and ajoenes, depending on factors like temperature, solvent, and pH [4]. While derivatives of allicin may offer greater stability, they exhibit significantly reduced bioactivity compared to pure allicin.

Allicin's lipophilic nature enables it to rapidly traverse cell membranes, where it reacts with free thiol groups of proteins [5]. As a broad-spectrum antimicrobial agent, allicin has demonstrated the ability to inhibit the growth of numerous gram-positive and gram-negative bacteria. Additionally, it exhibits anticancer properties by inducing apoptosis in various cancer cell lines [6]. Its therapeutic potential extends further, showcasing antioxidant, antimutagenic, antiasthmatic, immunomodulatory, hypocholesterolemic, hypolipidemic, antihypertensive, antidiabetic, antithrombotic, antirheumatic, and anti-hyperhomocysteinemia effects. Allicin is particularly promising in the treatment of cardiovascular diseases, where it enhances antioxidant levels, prevents cardiac hypertrophy, mitigates hyperlipidemia, promotes vasorelaxation, suppresses angiogenesis, and constrains platelet aggregation [6].

Despite its promising applications, allicin faces significant challenges that hinder its antimicrobial use, including a lack of comprehensive understanding regarding its (i) mode of inhibition on various bacterial targets, (ii) extraction yield and

recovery, (iii) synergy with other antibiotics, (iv) bacterial killing kinetics, (v) pharmacodynamics, and (vi) stability under different environmental conditions. This research aims to address these challenges and advance the bioprospecting of allicin.

The mechanism of protein inhibition is increasingly being elucidated through molecular docking techniques. This approach allows for the prediction of drug candidates' binding orientations against macromolecular targets, facilitating the assessment of drug affinity and activity. As a result, molecular docking has become an integral component of the drug design and discovery process, forming the foundation of modern drug development through an “in-silico–chemic-biological” approach [8]. In this study, docking was employed to evaluate allicin's mode of action against various growth-promoting proteins in different bacterial strains, as well as proteins involved in drug resistance. This analysis provided insights into the binding affinity of allicin with multiple targets responsible for bacterial growth, survival, and resistance.

To further advance this research, it is crucial to develop an effective extraction process to obtain allicin from garlic biomass. Extraction techniques are vital in the chemical, biotechnology, and pharmaceutical industries for retrieving phytopharmaceuticals from medicinal plants. Recent advancements in high-pressure extraction processes using eco-friendly solvents have demonstrated improved efficiency over traditional methods. However, these techniques often encounter low extraction rates for specific phytochemicals [9]. To overcome these limitations, ultrasound-assisted extraction techniques can enhance yield by increasing mass transfer and causing cell wall rupture through microcavitation. This approach not only boosts product yields but also reduces processing time and solvent consumption [10]. Additionally, surfactant-based extraction methods have proven effective for hydrophobic compounds, yielding high-quality extracts that can surpass other extraction techniques [11]. This study explores enhancing allicin extraction yield while minimizing the presence of unwanted phytochemicals through a micellization technique utilizing biocompatible Tween surfactants [12]. Surfactants can form micelles that entrap hydrophobic drugs, improving their solubility in aqueous phases and protecting them from degradation under varying physical and chemical conditions [13].

Ultimately, this chapter aims to comprehensively investigate the bioprospecting of the biopharmaceutical allicin through various advanced technologies. The conservation and proper bioprospecting of allicin from *Allium sativum* species remain largely unexplored. Thus, this research implements molecular docking, in silico processes, ultrasound-surfactant-based extraction, separation, purification, synergy studies, kinetics, pharmacodynamics, micellization, and PEGylation

Pharmacy Automation and Robotics

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Abstract: The potential for revolutionary robotic technology and Artificial Intelligence (AI) in the pharmacy and medicine sectors is highly promising. These innovations have the potential to bring about substantial changes in various aspects of healthcare. Their primary objectives include enhancing operational efficiency, promoting patient well-being, and reducing costs, while addressing significant challenges such as personalized medical treatments and the need for more effective therapies. Industrial automation and robotics refer to the application of computers, control systems, and information technology in the management of industrial processes and machines. This involves substituting manual labor with automated systems to enhance efficiency, speed, quality, and performance. Automation and robotics have become essential elements in the rapidly evolving field of pharmaceutical practice. The field of robotics has garnered global attention, particularly within the pharmaceutical business, in recent years. Robots are primarily developed for industrial applications, where production occurs on a massive scale. Robots, which are robotic devices, are mostly created for industrial purposes. They play a crucial role in various areas, including packaging medicines, conducting research and development in laboratories, and maintaining cleanliness. Due to the progress in the design and functionality of robots, the field of technology has experienced significant growth. Robotics encompasses the scientific and technological study of robots, as well as their design, development, manufacture, and application. Robotics plays a crucial part in the intricate processes of research and development, production, and packaging in the pharmaceutical industry. The rationale for using robots varies, ranging from enhancing worker safety to improving quality. Robotics offers the advantage of expediting the drug discovery process. Several manufacturers of robots offer devices specifically tailored for this market. The future of industrial robotics in the pharmaceutical sector is promising. The growing need for advanced medical devices and novel pharmaceuticals to serve an aging population has led to the increasing adoption of robotics systems to enhance productivity and efficiency. Nevertheless, industrial robotics firms encounter numerous obstacles in their endeavor to develop a presence in pharmaceutical applications.

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Keywords: Medication dispensing, Medication errors, Patient safety, Pharmacist empowerment, Pharmacy automation, Robotics in healthcare.

INTRODUCTION

The healthcare sector is poised for innovation. The United States spends over 50% more per capita on healthcare compared to many other advanced countries, with this expenditure constituting 17.8% of the country's Gross Domestic Product (GDP) [1]. There is a suggestion that the greater utilization of technology and automation in the field of healthcare could lead to improved patient care and decreased overall expenses [2]. Pharmacy leaders face ongoing pressure to reduce expenses while delivering pharmaceutical treatment that is both safe and efficient.

Human error is inevitable. Estimates for the number of medical errors that occur in hospitals in the United States have increased significantly from 98,000 to 400,000 since *To Err is Human: Building a Safer Health System* was published in 1999 [3, 4]. To reduce these errors, potential problems must first be identified and then measured and reported before systems can be designed to mitigate the problems.

One subset of medical errors is Medication Errors (MEs). Medication errors have previously been defined as “any error occurring in the medication-use process” [5]. Due to differences in how MEs are determined, there is a wide range in the number of MEs reported in both inpatient and outpatient settings [6]. Flynn *et al.* found a 17.9% ME rate in hospitals and skilled nursing homes when multiple detection methods were used [7]. This high rate is important because MEs can lead to drug complications, the most common cause of adverse events in hospitalized patients [8].

The intricacies involved in the medicine-use process contribute to the overall frequency of Medication Errors (MEs). Fig. 1 outlines the primary stages of the medication-use process, and each stage might use different technologies. Complications arise when workflows lack standardization. This issue frequently arises from the absence of interoperability among systems and the inherent unpredictability of human behavior that arises when healthcare personnel utilize these technologies. Collectively, these systems, behaviors, and interactions make it more challenging for us to comprehend the potential areas of failure in the pharmaceutical use process and how they might be addressed. The preparation and delivery of pharmaceuticals typically occur in pharmacies, often involving a combination of pharmacy automation and robotics systems alongside human intervention. Pharmacy robotics refers to mechanical systems capable of executing planned, intricate, and repetitive actions that mimic human behavior, all without the need for constant operator input [9].

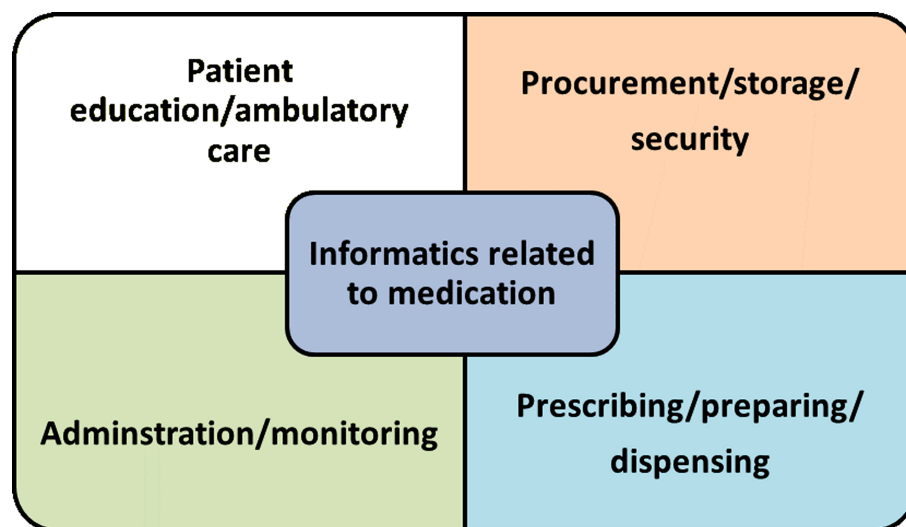


Fig. (1). Informatics within the medication use system.

The inception of Randomized Controlled Trials (RCTs) commenced in the 1940s with the aim of mitigating the bias identified in study procedures. During the 1980s, the Randomized Controlled Trial (RCT) gained recognition as the most reliable and authoritative form of medical evidence. While Randomized Controlled Trials (RCTs) have been the norm in pharmaceutical research, their application in other domains that impact medical usage, such as the integration of technology, has proven to be challenging. The prudent and methodical process of medicine approval stands in stark contrast to the rapid and dynamic nature of technology development and innovation. Although there are difficulties in implementing Randomized Controlled Trials (RCTs), they remain the most reliable and prestigious method in medical research, leading to significant advancements in healthcare quality [10]. The question remains: Should pharmacy automation and robotics systems be tested in a similar, robust manner to prove their efficacy and safety?

A key factor driving the increasing adoption of automation and technology in the medication-use process is the widely held perception that it enhances patient safety and reduces pharmacy errors [11, 12]. Nevertheless, the introduction of novel technology can give rise to new challenges in the process of drug utilization due to an incomplete understanding of all elements during implementation. Despite the presence of an intravenous (IV) automated IV workflow system at a hospital in Bend, Oregon, a patient safety incident occurred. The IV workflow system was not utilized due to a conflict that arose with their recently implemented Electronic Health Record (EHR). The compounded pharmaceutical

CHAPTER 11

Technologies in Pharmacy Education**Sukirti Upadhyay^{1,*}, Prashant Upadhyay¹ and Neeraj Kumar Fuloria²**¹ *School of Pharmaceutical Sciences, IFTM University, Moradabad, Uttar Pradesh, India*² *Pharmaceutical Chemistry Unit, Faculty of Pharmacy, AIMST University, Kedah, Malaysia*

Abstract: Pharmacy education has advanced significantly in recent years. Despite classroom teaching, the education system has adopted various ICT tools. So, in this chapter, various new processes and technologies are discussed. Pharmacy education has embraced various technologies to enhance learning experiences. Virtual reality simulations, online modules, interactive apps, and electronic health record systems are just a few examples. Although there may be issues related to privacy, financial limitations may arise in the case of developing countries. These technologies offer immersive learning environments, facilitate collaboration, and provide real-world practice scenarios for students. They are designed to enhance the understanding of subjects in B.Pharm and M.Pharm programs. Nowadays, education is oriented toward a better understanding of subjects with a focus on skill development, employability, and entrepreneurship.

Keywords: AI, Mobile, Modules, Pharmacy education, Technology, Virtual.

INTRODUCTION

In pharmacy education, new technologies are revolutionizing the learning experience. Virtual reality simulations provide hands-on training in compounding and patient counseling, while artificial intelligence is utilized in drug discovery and the development of personalized medications. Mobile apps provide access to drug information and enhance collaborative learning, while telemedicine platforms expand opportunities for remote clinical experiences. Embracing these technologies prepares future pharmacists for the evolving platform of healthcare delivery. The following methods are currently used in pharmacy education to enhance student learning of various subjects, including jurisprudence, pharmaceutical microbiology, biotechnology, pharmaceutical chemistry, pharmacology, pharmacognosy, pharmaceutical management, and pharmaceutical microbiology.

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Pharmacy education has now used different technologies to enhance the learning process. This chapter discusses examples of technology use in pharmacy education.

Simulation Software

Students can practice clinical scenarios in a secure setting by using virtual simulations. As simulation software provides students with dynamic, hands-on learning experiences, it is essential to pharmacy education. Using these resources, students can rehearse patient counseling, medicine administration, and clinical scenarios in a safe virtual setting. With the aid of these lifelike simulations, which accurately replicate actual pharmacy environments, students can enhance their critical thinking, decision-making, and communication skills. Furthermore, simulation software is a useful teaching and assessment tool for pharmaceutical skills, as it can be customized to meet specific learning objectives and modified in response to students' progress [1].

Mobile Apps

Applications facilitate mobile learning by offering access to drug databases, medical calculators, and instructional materials. These applications include:

EdApp

EdApp is a free, all-in-one learning management system (LMS) that offers a vast selection of pharmacy courses in its editable course library, along with a robust and user-friendly course creation tool.

Chameleon Creator

This tool is ideal for creating fully responsive e-learning materials. Fully responsive content can be viewed and accessed on all types of devices, regardless of screen size or resolution, making it especially useful for presenting complex pharmaceutical information. The creator tool is user-friendly, and its customizable elements interact dynamically with the content.

EduMe

EduMe is an online creator tool that focuses more on visual media than text-based lessons. It is an effective tool for building pharmacy courses, as visual representation is one of the most effective ways to deliver various pharmacy lessons. Topics, such as dosages and types of medicine, benefit from images that help reinforce learning.

Kitaboo Insight

Kitaboo Insight is a mobile-friendly learning management system that is used to deliver cloud-based training to all kinds of mobile devices. It is compatible with all operating systems, so whether you use iOS or Android, it will work. Existing content from PDFs, PPTs, and text files can be uploaded to the course creator, then customized with quizzes, interactive templates, and various knowledge checks. The platform is simple and easy to use, and the content can even be accessed offline.

Adaptive U

For those who are just getting started with e-learning course creation, Adaptive U is the tool to build the desired pharmacy course. It is a simple course builder that allows you to copy and paste content, including images, videos, and articles. Slide design for branding is also relatively simple, as there are a variety of colors to choose from that match your company's brand. Aside from content creation, Adaptive U also offers reporting and analytics, which are essential for any learning management system.

GLO makers

GLO makers is an open-source online pharmacy course builder that allows you to build rich and interactive learning content. However, this is a more technical course-building software. The creation process is divided into planning and designing, with a tool for each step. The planner tool provides users with instructional design tips and tutorials on storyline design to help them create effective learning lessons.

Forma LMS

For building pharmacy tech courses online, Forma LMS may be an ideal tool. Forma LMS has a responsive interface optimized for easy navigation and user experience, which benefits both beginners and course creators. The tool supports various e-learning formats, such as HTML, SCORM, and video. User management, course assignment, reporting, tracking, and other administrative tasks can also be automated.

Abara LMS

Abara LMS is a tool for building pharmacy courses and software that simplifies all training processes. Course creation and all assessment types are mobile-based, making everything much more accessible. It is also SCORM-compliant, so integration with existing SCORM materials is easier. Beyond course creation,

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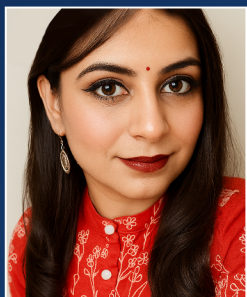
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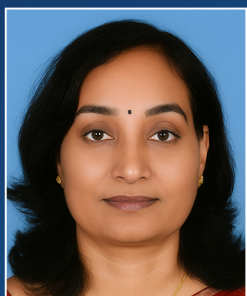
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