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Exploring the Role of Artificial Intelligence in Pharmacy and Pharmacy Practice

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ABSTRACT
Artificial Intelligence (AI) is rapidly transforming the field of pharmacy and pharmacy practice, offering unprecedented opportunities to enhance personalize medicine, optimize medication management, and improve patient outcomes. Artificial Intelligence technologies, such as machine learning, natural language processing, and robotics, are being utilized to analyze vast datasets, automate routine tasks, and support clinical decision-making. Artificial Intelligence capacity to analyze large datasets, predict outcomes is revolutionizing how pharmacists and healthcare providers approach patient management and pharmaceutical services. This review explores the various applications of Artificial Intelligence in pharmacy, including its role in accelerating drug development, tailoring treatments to individual patients, managing medication inventories, and providing real-time clinical recommendations. Personalized medicine is another significant area where Artificial Intelligence makes a difference. By analyzing genetic data, AI helps tailor drug therapies to individual patients, minimizing adverse effects and maximizing efficacy. Additionally, AI tools enhance pharmacy operations by automating routine tasks such as medication dispensing and inventory management, leading to greater efficiency and reduced human error. By examining current advancements and their implications, this paper highlights the potential of Artificial Intelligence to revolutionize pharmacy practice while ensuring that ethical standards and regulatory requirements are met.This review concludes by discussing future prospects, emphasizing that ongoing Artificial Intelligence innovations will continue to shape and enhance pharmacy practice, driving improvements in drug development, patient care, and operational efficiency. It aims to offer a holistic understanding of how Artificial Intelligence is reshaping the Pharmacy and its implications for the futureof Pharmacy Practice.

KEYWORDS: Artificial Intelligence, personalized medicine,medication management, clinical decision support, healthcare technology, current scenario, future perspective,regulatory challenges.

I. INTRODUCTION

The simulation of human processes by machines, particularly computer systems, is known as artificial intelligence (AI). which includes the machine-demonstrated perception, synthesis, and inference of information [1]. It can also mean that a computer or a robot under computer control is able to perform tasks that are typically performed by people only when they call for human intelligence and judgment. A method of artificial intelligence called machine learning (ML) teaching an algorithm or model to generate predictions based on incoming data [2].

Across the world, artificial technologies are being used in healthcare settings, necessitating

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the engagement of pharmacists. As front-line healthcare providers, pharmacists regularly interact with patients. When it comes to utilizing technology to enhance patient outcomes and experiences, pharmacists are crucial. Artificial intelligence (AI) would significantly enhance healthcare across the board, from diagnosis to therapy. Artificial intelligence can bring improvements to any process within healthcare operation and delivery [3].

intelligence

Artificial Intelligence helps in administrative workflows, image analysis, robotic surgery, virtual assistants, and clinical decision support. In 2020 Baidu releases the Linear Fold AI algorithm to medical and scientific and medical teams developing a vaccine during the early stages of the SARS-CoV-2 (COVID-19) pandemic. The algorithm can predict the RNA sequence of the virus in only 27 seconds, which is 120 times faster than other methods [4].

In the realms of medicine and technology, the term 'innovate' often signifies incremental advancements within a new context. Some of these technologies promise to enhance service capabilities and outcomes, while others may inadvertently hinder practitioners' abilities to add value and secure compensation for their activities. In recent years, the convergence of healthcare and technology has catalysed significant advancements in patient care, clinical decision-making, and pharmaceutical innovation [5].

In the realm of pharmacy, artificial intelligence holds immense promise for revolutionizing traditional practices, optimizing medication management, and improving patient outcomes. Healthcare is increasingly driven by new technologies that have the potential to transform system efficiency and patient experience. Artificial intelligence offers solutions to these challenges by providing intelligent algorithms and tools to assist pharmacists in medication selection, dosing optimization, and therapeutic monitoring. In drug discovery, artificial intelligence algorithms accelerate the identification of novel drug targets, lead compounds, and therapeutic interventions, expediting the drug development pipeline and bringing new treatments to market more rapidly. It continues to evolve and permeate every facet of healthcare, including pharmacy practice and management, pharmacists need to embrace this technology and adapt to the changing landscape of healthcare delivery [6].

II. DEFINITION AND BASICS

Artificial Intelligence, originally unstructured around the field of rules, was introduced and developed before the start of Machine Learning. AI as we learned to bring computers to areas where humans excel, we tended to use rules to solve specific tasks. Machine Learning enables the same results but is based on statistical predictions. Deep learning is a sub-field of ML that tries to imitate the way a human brain works.

It uses artificial neural networks to interpret data in an unsupervised manner. It is based on representation learning, in which higher levels of the task's hierarchy are defined with automated inspiration, and abstraction is extracted from raw data rather than handcrafted data.

Artificial intelligence is a branch of computer science that deals with the simulation of intelligent behaviour in computers, the development of intelligent computer programs to perform specific tasks, expert systems, and the building of robotics capable of human-like decision-making and running intelligent machines.

III. SCOPE OF ARTIFICIAL INTELLIGENCE IN PHARMACY & PHARMACY PRACTICE

a) Personalized medicine: Artificial intelligence is used in personalized medicine to customize patient care by utilizing information from genetic, environmental, and lifestyle sources. Artificial intelligence (AI) systems can provide tailored medication regimens that maximize therapeutic efficacy and reduce side effects by combining and analysing this data, enabling more accurate and efficient healthcare [7].

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b) Medication management: By automating processes like inventory control, prescription filling, and dispensing, AI enhances pharmaceutical management. Accurate medication administration is ensured by automated dispensing devices, which lower the possibility of human error. AI-driven inventory management forecasts prescription demand, assisting pharmacies in keeping the right amount of stock on hand and preventing shortages [8].

c) Medication adherence and patient monitoring: Artificial intelligence (AI)-enabled solutions help patients who are at risk of not taking their medications as prescribed by employing predictive analytics. In order to increase adherence, smart pill dispensers, wearable technology, and smartphone apps with AI integration detect patient medication consumption and send out reminders or notifications. Artificial intelligence also makes it easier to monitor patients remotely, giving medical professionals the ability to track patient health data in real time and take immediate action when necessary [9].

d) Predictive analytics for patient outcomes: AI utilizes predictive analytics to forecast patient outcomes based on historical data and current health status. By analysing patterns in patient data, AI models can predict disease progression, treatment responses, and potential complications, enabling proactive management and personalized treatment plans [10].

IV. HISTORY

a) Foundations and early developments (1960$_s$-1980$_s$)

Birth of AI: The term "Artificial Intelligence" was coined at the Dartmouth Conference, marking the formal beginning of AI research. Although not specific to pharmacy, this period laid the foundation for future AI applications in various fields, including pharmacy [9].

b) Early expert systems (1980s-1990$_s$)

Developed in the 1970s but influential through the 1980s, MYCIN was one of the first expert systems for clinical decision support, laying groundwork for future pharmacy applications [11].

c) Clinical decision support systems (1990$_s$-2000s)

Development of Pharmacy-Specific CDSS: AI-driven systems for drug interaction checking and patient-specific recommendations were developed and refined during this period [12].

d) Pharmacogenomics and personalized medicine (2000$_s$-2010$_s$)

Integration of AI in Genomics: AI began to play a significant role in analysing genetic data to tailor drug therapies, marking a shift towards personalized medicine [13].

e) Natural language processing (nlp) and big data (2010$_s$)

NLP Applications: Advances in NLP allowed for the extraction and analysis of unstructured data from electronic health records (EHRs), enhancing pharmacy practice [14].

f) AI in drug discovery and development (2010$_s$-present)

AI-Driven Drug Discovery: The use of AI in drug discovery has accelerated the identification of new drug candidates and optimized drug development processes [15].

g) Automated pharmacy operations (2020$_s$-present)

Robotic Dispensing and AI Integration: AI and robotics are increasingly used in automating pharmacy operations, including dispensing medications and managing inventory [16].

h) AI in drug safety and pharmacovigilance (2020$_s$-present)

Predictive Models for Drug Safety: AI models are used to predict adverse drug reactions and improve safety monitoring [17].

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i) Artificial Intelligence and patient-centric care (2020s-present)

Chatbots and Virtual Assistants: AI-driven chatbots and virtual assistants are increasingly used to support patient interactions, medication adherence, and personalized health information [18].

J) AI in pharmacy education and training (2024)

AI-Enhanced Learning: AI technologies are now being integrated into pharmacy education and training programs to provide personalized learning experiences and simulations [19].

USING AI IN CHALLENGES IN PHARMACY PRACTICE

DATA PRIVACY AND SECURITY

The widespread of artificial intelligence rise concerns about data privacy and security. Health information is sensitive and thus Patient data is critical. Some patients may be concerned that their data collection will infringe on their privacy, and lawsuits have been filed in response to data-sharing between large health systems and AI developers[56]. Patient consent is an important factor in data privacy concerns, as healthcare organizations may allow the large-scale use of patient data for AI training without obtaining sufficient individual patient consent [21].

DATA INTEGRATION

The next challenge of artificial intelligence is that it may have too many variable parameters in relation to outcomes using inappropriate features [22]. When using small amount of data, it produces results with good accuracy. Sometimes text, numeric, image, and video data must be integrated using the same algorithm, which is one of the most difficult challenges in medical data processing [23,24].

PATIENT SAFETY

Hospital data can occasionally be of low quality, incorrect, or lacking certain data pieces. This results in data inaccuracy, which is one of the hardest problems when utilizing AI to process medical data [24]. Another problem is ML algorithm judgment errors, which occur when an algorithm is applied incorrectly or when the data is not trustworthy enough to be employed [34].

AI IN HOSPITAL PHARMACY

AI's cutting-edge technologies seamlessly and synergistically integrate their responsibilities, clinical pharmacy practice is about to undergo a revolution. Especially in hospital settings, it provides pharmacists with an unmatched opportunity to improve their collaboration with clinicians. By providing real-time updates on patient medications, possible drug interactions, and dose recommendations drawn from integrated patient data, AI-driven solutions facilitate communication between pharmacists and physicians[21].

These smooth integrations. emphasize the importance of pharmacists as vital members of medical teams who guarantee patient safety and therapeutic efficacy. Artificial intelligence (AI) can suggest suitable medicinal regimens, doses, and combination drugs because of its ability to comprehend enormous volumes of patient data and clinical recommendations.

For example, IBM Watson for Oncology is an AI-driven tool that aids oncologists in pinpointing potential cancer drug treatments tailored to individual patient profiles. AI plays vial role identifying medication errors. has the capacity to forecast adverse events in hospitals and create preventative actions, improving patient safety and the standard of care overall [22].

By forecasting health trajectories based on existing treatment plans and patient health histories, AI's predictive analytics capabilities also have the potential to expedite patient care. Heart failure patients' hospital readmission rates can now be predicted with precision by tools like Google DeepMind, giving pharmacists more precise tools to tailor therapy plans [25].

In general, artificial intelligence (AI) can free up clinical pharmacists to focus more of their time on providing excellent, patient-centred care than on administrative tasks. This will enhance

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patient outcomes as well as the pharmacists' sense of professional fulfilment and job satisfaction.

AI IN COMMUNITY PHARMACIES

AI has the potential to transform community pharmacy practice and have an impact that goes beyond the duties of pharmacists. AI improves supply chain management. Artificial intelligence algorithms have the capability to examine an extensive range of data in order to forecast demand for different pharmaceuticals. This data includes prior sales, seasonality, local health trends, promotional activities, and even external factors such as weather patterns or disease outbreaks.

By doing this, pharmacies are able to keep an ideal stock level and reduce the likelihood of stockouts and overstocks when popular items run out of stock or expire before they are sold. AI also automates the reordering procedures to keep the right amount of inventory on hand. This system can assist ensure that necessary pharmaceuticals are always easily accessible for purchase while also saving staff time by automatically issuing purchase orders to replenish inventories when levels fall below certain criteria and monitoring stock levels in real-time [26].

Automated Dispensing Systems (ADSs) can be enhanced using AI. Artificial intelligence has the potential to greatly improve dispensing accuracy and precision, learn from mistakes made in the past, and use machine learning techniques for ongoing system optimization.

Artificial intelligence can further simplify the prescription process, from prescription generation to billing. AI's capacity to cross-reference medication that is dispensed with patients' medical records adds an additional layer of protection by instantly informing pharmacists of any potential drug interactions or patient allergies, significantly improving patient safety [27].

Artificial intelligence advances the monitoring of public health. Large-scale health data sets can be analysed by AI systems to find patterns in drug use, disease outbreaks, and other public health issues that can call for pharmacists or public health agencies to take action. Pharmacy employees can concentrate on higher-value services like patient counselling and care by automating duties like drug dispensing and inventory management. This may lead to the creation of new revenue streams in addition to improving service quality. AI-powered applications that can improve patient engagement include chatbots and automatic reminders [28].

APPLICATIONS OF ARTIFICIAL INTELLEGENCE IN PHARMACY

CLINICAL APPLICATIONS:

Using clinical decision support systems (CDSS), pharmacists have employed AI to provide data-driven interventions in a variety of healthcare contexts. This kind of technology assists the pharmacist in gathering information and taking appropriate action to reduce patient difficulties, avoid prescription errors, and save expenses. Local pharmacies also started using CDSSs [4]. Artificial intelligence is used in outpatient therapy as well. The application of CDSS in practice may be hampered by a number of its negative effects, including a lack of official incentives to employ the technology, a lack of patient decision support results, and a lack of consistent input to physicians [29].

MEDICATION MANAGEMENT:

A huge number of individuals suffer tragic consequences due to the impact of the medication error including loss of life and unreported adverse reactions or complications. These errors create a heavy financial burden. Medication errors undermine the trust that patients place in the healthcare system. Incorrect patient identification and medication administration are two of the most prevalent medication errors [30,31].
These errors include incorrect dosing, improper medication selection, and errors in monitoring patients with liver or kidney disease or allergies [34].
Artificial intelligence (AI) can serve as a valuable tool to aid pharmacists in enhancing patient safety and minimizing errors [31].

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OPTIMIZED MEDICATION SELECTION:

A crucial step in ensuring the greatest potential treatment outcome for each patient is optimized drug selection. probable adverse effects and interactions with drugs. After analysing all of the data, 20 pharmacists are able to make recommendations that will reduce pharmaceutical risks and increase therapeutic benefits. This customized approach recognizes that due to variables such genetic variances, pre-existing diseases, and polypharmacy [33].

Artificial intelligence offers the ability to customize medical interventions for specific patients or patient groups according to their disease profile, diagnostic or prognostic data, or response to treatment. The customized treatment plan will take into account genetic differences in addition to characteristics that affect medical therapy, including age, gender, race, location, family history, immunological profile, metabolic profile, microbiota, and susceptibility to the environment.

This means collecting data from individuals such as genetic information, physiological monitoring data, or EMR data and tailoring their treatment based on advanced models [34]. AI-based systems can provide pharmacists with advanced decision-support tools. and addressing active lifestyles [35].

Pharmacists provide extended services, educate patients, and promote a treatment adherence. the integration of AI technology offers pharmacists a comprehensive understanding of each patient's unique needs, enabling personalized interventions. It can evaluate massive volumes of data and actively engage patients by making individualized recommendations and therapies [36]. Large volumes of patient data from diverse sources, including as genomic sequencing, electronic health records, medical reports, and lifestyle data, are analysed by it. AI can understand individual patients' unique characteristics and medication needs [37,38].

Artificial Intelligence aids in the interpretation of pharmacogenomic data, determining the potential impact of a person's genetic composition on their reaction to particular drugs. Artificial intelligence (AI) technologies offer insights into the best pharmaceutical choices and dosage modifications based on a patient's genetic profile [39]. AI models estimate the likelihood of therapeutic success and identify patients who may be at a higher risk of adverse reactions [40,41].

It aims to provide personalized and dynamic treatment plans that are tailored to each patient's unique characteristics and evolving needs, leading to improved treatment efficacy, minimized side effects, and ultimately provide better patient care [42,43].

PREDICTING ADVERSE DRUG REACTION:

Medication errors that put patients at serious risk include adverse drug events, adverse drug reactions, and drug interactions. These errors are big concerns in the healthcare industry. But the use of AI technology presents a viable way to improve these reactions' management and prediction [44].

Deep learning and convolutional neural networks are two examples of AI systems that are capable of processing enormous volumes of data and spotting complex relationships between medications and side effects, interactions, and adverse occurrences. These forecasts are the result of an analysis of a variety of data sources, including adverse event and adverse reaction reporting systems, drug databases, clinical trial data, and electronic health records.

Artificial intelligence algorithms can uncover relationships and risk factors of medications that may not be visible to human experts [45]. Artificial intelligence systems have the ability to check for possible medication interactions, including those between drugs and diseases, and can notify patients and healthcare providers of any such interactions.

Artificial intelligence is able to evaluate possible drug interactions and notify pharmacists of them, providing advice on how to change dosages or select substitute treatments [46,47]. When new data becomes available, the AI models are constantly

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learning and adapting, which improves the forecasts' accuracy and dependability over time [48].

ROBOTIC DISPENSING INTEGRATED WITH AI TECHNOLOGY

Pharmacy dispensing robotics is one of the key technologies driving the advancement of hospital pharmacy systems. The use of robotic support helps to reduce human mistake. Both patient safety and dispensing accuracy can be enhanced by robots [50]. Its ability to identify and locate thousands of different medications enhances the efficacy and efficiency of the distribution process

Patients may retrieve prescription medications more easily with the help of the robot, which connects to the hospital's electronic order entry system and displays instructions on a screen. The drug preparation is then sent using the prescription data from the automated order entry system[49].

INVENTORY MANAGEMENT

The use of AI in inventory management allows for precise forecasting of future drug requirements. Based on previous sales data, pharmacists can predict the demand for particular pharmaceuticals [50]. Pharmacists can maximize their inventory levels and make sure they have the correct medications on hand thanks to these predictive capabilities [51,52].

When a drug is about to expire, AI systems can watch and monitor its expiration dates and change a pharmacist's advance. By using this strategy, pharmacists can reduce the possibility of giving patients outdated prescriptions, protecting their safety [53].

PATIENT CARE

Beyond their typical job in operating pharmacies, pharmacy managers play a significant role in patient-centred care. They serve as trainers, assisting patients in taking up active lives, quitting smoking, and adopting good eating habits. This is particularly valid for the management of long-term illnesses. In the meantime, by having a complete understanding of each patient's unique needs, pharmacists may deliver tailored interventions thanks to the application of AI technology.

Artificial intelligence has the capacity to analyse vast amounts of data and can actively involve patients by offering individualized treatment plans and recommendations. As a result, people are empowered to actively manage their health, improving health outcomes and boosting adherence. AI capabilities combined with pharmacy experience allow pharmacist services to grow, becoming more personalized, effective, and available [51].

CURRENT SCENARIO

In pharmaceutical industry artificial intelligence is quite helpful for organizing data and presenting findings, which improves decision-making and helps save time, money, and human labour. Numerous businesses are operating their healthcare operations using conventional methods. It makes the pharmaceutical industry cost effective, hassle free and saves time.

Google’s healthcare project Deep Mind (developed by Google) helps to mine patient data in a short time. Therefore, this project is useful for better and faster treatment. Moor fields Eye Hospital NHS is supporting this project to improve eye care [54].

Medical Sieve (an algorithm pioneered by IBM) is a "cognitive assistant" with good analytical and reasoning skills. A medical startup is essential to improving patient conditions by combining deep learning with medical knowledge. A special computer program is available for each part of the body that is used for certain diseases. Deep learning can be used in almost all types of image analysis such as X-ray, CT scan, ECHO, EKG, etc [55].

Molly (a virtual nurse designed by a startup) is given a pleasant voice and a hearty face. It aims to help guide patient care and support chronic disease patients during doctor visits[61]. Ai Cure is a smart webcam application that monitors patients and helps them manage their condition. This application is useful for patients with serious

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drug-related situations and patients participating in clinical trials [56].

"Open AI Ecosystem" was one of the ten most promising technologies in 2016. It is useful to collect and compare data on social awareness algorithms. Extensive information is stored in the health system, which includes the patient's medical history and treatment information from childhood to this age. This huge data can be analysed through ecosystems and recommendations can be made about the patient's lifestyle and habits [57].

Artificial intelligence and machine learning can significantly enhance various areas of research and development, which could lead to a higher chance of successful drug development. These areas include ethical conduct, and evaluation of clinical experiments.

FUTURE PERSPECTIVE

Pharmacists will gain access to extraordinary tools and resources that will enhance medication management, treatment optimization, and patient outcomes. Personalized medicine will be a reality, as Artificial intelligence algorithms analyse patient-specific data to customize treatment plans and predict individual responses to medications. AI-driven systems will efficiently organize pharmacy workflows, automating repetitive tasks and freeing up pharmacists' time for patient care and counselling. Artificial intelligence in pharmacy holds immense promise in transforming healthcare delivery and elevating patient care to unprecedented levels [4].

Artificial intelligence systems have the ability to sort through many types of data, such as clinical, proteomic, and genomic data, in order to identify novel targets for treatment. Through the identification of disease-associated targets and molecular pathways, artificial intelligence (AI) assists in the development of medications that can regulate biological processes.

Large chemical libraries can be quickly screened by artificial intelligence to identify possible medications with a high binding affinity for a certain target. By prioritizing and choosing compounds for experimental testing based on projected binding affinities and simulations of chemical interactions, scientists can use artificial intelligence (AI) to save time and resources.

Artificial intelligence systems may suggest new chemical compounds like drugs using generative models and reinforcement learning. To help create new medication candidates, It learns from chemical libraries and experimental data, which increases the chemical space [58].

Pre-clinical targets can be identified by applying natural language processing (NLP) to extract scientific information from biomedical literature, unstructured electronic medical records, and insurance applications. On the other hand, predictive modelling can predict protein structures and help with the creation and optimization of chemical compounds, making it possible to identify more potential therapeutic candidates. Using "big data" from real-world sources, these methods also help with post-marketing research in three ways: (i) improving our knowledge of a drug's benefit-risk profile, (ii) illuminating patterns in treatment sequences, and (iii) pinpointing subsets of patients that might reap more benefits from a particular treatment than others [59,60].

AI-driven telepharmacy services will expand, providing remote consultations, medication management, and chronic disease monitoring. Enhanced AI algorithms will facilitate more accurate diagnosis and treatment recommendations, particularly in underserved areas[61]

V. CONCLUSION

Artificial Intelligence (AI) has the ability to personalize patient care, streamline administrative procedures, and enhance decision-making based on data-driven insights, with its ability it has great promise to transform pharmacy practice. This technology will greatly improve operational efficiency in a number of areas, including stock management automation, drug demand prediction, and improved dispensing accuracy.

In the meantime, it improves health outcomes and develops loyalty through patient

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participation and education. Predictive analytics and AI's capacity to analyse vast volumes of data can improve quality control procedures, guide preventative care plans, and reveal business prospects. AI will therefore have a significant impact on how pharmacy develops in the future by ensuring that pharmacists will have greater job satisfaction and that pharmacy practices will be more profitable and effective. Additionally, it will advance and enhance the healthcare system by automating everything. AI systems will augment their efforts to care for patients.

The integration of Artificial Intelligence in pharmacy practice also promises to reduce healthcare costs by automating routine tasks, minimizing medication errors, and enabling proactive patient management. However, the successful implementation of AI requires careful consideration of ethical concerns, such as data privacy, bias in algorithms, and the need for robust regulatory frameworks to govern AI applications in healthcare.

In conclusion, Artificial Intelligence is set to play a pivotal role in the future of pharmacy, driving innovations that will enhance every aspect of the field, from drug development to patient engagement. As pharmacists and healthcare professionals continue to embrace these technologies, the potential for Artificial Intelligence to improve health outcomes and operational efficiency will only grow, marking a new era in pharmacy practice.

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