WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.453
Volume 14, Issue 23, 298-314. Review Article ISSN 2277–7105

REVIEW ON:- AI IN PHARMACY

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Article Received on 28 Oct. 2025,
Article Revised on 18 Nov. 2025,
Article Published on 01 Dec. 2025,
https://doi.org/10.5281/zenodo.17746885

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How to cite this Article: Miss. Khushi S. Kothari, Miss. Lochani S. Gajbhiye, Miss. Akanksha W. Bhute, Prof. Vishnudas Lokhande, Dr. Rahul Bijwar. (2025). REVIEW ON:- AI IN PHARMACY. World Journal of Pharmaceutical Research, 14(23), 298–314.

ABSTRACT

Artificial Intelligence (AI) is revolutionizing pharmacy practice by enhancing efficiency, accuracy, and personalized patient care. This review evaluates the integration of AI tools such as IBM Watson, Medisafe, ScriptPro, and BenevolentAI into various pharmaceutical functions, including drug discovery, medication management, clinical decision support, pharmacovigilance, and inventory systems. AI applications in pharmacy contribute to optimizing operations by automating prescription verification, predicting medication adherence, minimizing dispensing errors, and enabling real-time inventory control. In drug development, AI accelerates the identification of potential candidates and repurposes existing drugs, as demonstrated during the COVID-19 pandemic. Furthermore, AI supports personalized medicine by analyzing genetic data and tailoring treatments to individual patient profiles. Clinical decision support systems assist pharmacists by identifying drug interactions, contraindications, and suggesting evidence-based therapies. Despite these advances, the deployment of AI faces challenges such as data privacy, system integration, algorithm reliability, and ethical concerns, including accountability and potential workforce displacement. This review emphasizes that AI should complement—not replace— pharmacists, enhancing their capacity to provide informed, patient-centric services. Additionally, the use of large-scale pharmacy databases (WHO, FDA, IQVIA) for training AI models further strengthens its clinical utility. The results demonstrate that AI holds transformative potential in pharmacy, ensuring improved healthcare delivery, reducing adverse drug reactions, and promoting personalized treatment approaches. To fully harness AI, pharmacists must embrace digital tools, undergo adequate

training, and adapt to evolving regulatory frameworks. As AI technology advances, its thoughtful and ethical integration will play a pivotal role in shaping the future of pharmaceutical care.

KEYWORDS: Artificial Intelligence, Pharmacy Practice, Drug Discovery, Personalized Medicine, Medication Management, Pharmacovigilance, Clinical Decision Support, Ethical Issues.

INTRODUCTION

AI is a stream of science related to intelligent machine learning, mainly intelligent computer programs, which provides results in a similar way to the human attention process.[1] This process generally comprises obtaining data, developing efficient systems for the uses of obtained data, illustrating definite or approximate conclusions, self-corrections, and adjustments.[2] In general, AI is used for analyzing machine learning to imitate the cognitive tasks of individuals.[3] Pharmacy has also done a great job of leveraging enabling technology automation to improve workflow efficiency and lower operating costs while promoting safety, accuracy, and efficiency in every pharmacy setting. Automated dispensing gives pharmacists more time to engage with a greater volume of patients while also enhancing their health outcomes.[4]

There have been several expert systems developed in medicine to assist physicians with medical diagnosis.[5] Recently, several programs focusing on drug therapy have been described.[6]

The purpose of this article was to review topics related to AI. The topics include AI general overview and classification, AI uses in hospitals, the pharmaceutical industry, and retail pharmacies and to create awareness for AI as a component of pharmacy practice in the future, to encourage pharmacists to embrace this advancement, and as much as possible put in the effort to acquire the relevant skills, which will enable pharmacists to contribute towards the much-envisaged development.

As the pharmaceutical industry increasingly adopts AI, it holds the promise of making healthcare more precise, efficient, and patient-centered. However, challenges such as data privacy, ethical concerns, and the need for regulatory frameworks must also be addressed to ensure the safe and effective integration of AI into pharmacy practice.

AI GENERAL OVERVIEW

The term AI (also known as machine intelligence) is very commonly confused and used interchangeably with robotics and automation. While robotics is simply the creation of machines that can carry out difficult repetitive tasks, AI refers to the exhibition of human-like behaviors or intelligence by any computer or machine.[7] Traditionally, robots were not built to possess these "intelligent capabilities" even though they may be able to move or carry objects independently using a designed program and surface sensors in a process known as automation. AI, in essence, is the field of computer science that specializes in the creation of intelligent machines, developed with the ability to perform tasks that will ordinarily be associated with a human being.[8]

AI is frequently applied to the development of digital computers or computer-controlled robots with the capacity to autonomously execute intellectual and cognitive human-like processes. Such intellectual and cognitive processes include learning, reasoning, problem-solving, perception, and language. The form of AI currently in use today is referred to as narrow AI or weak AI because it is only designed to perform narrow tasks like internet search, facial and voice recognition, controlling and driving cars, and so on. However, the long-term goal of the AI community is to have machines that can autonomously outperform humans' at all cognitive tasks. The AI that involves creating machines that can perform all human cognitive tasks will be the general AI or Strong AI (ADI).[9]

AI IN THE LIFECYCLE OF PHARMACEUTICAL PRODUCTS

Considering that AI can help with rational drug design, decision-making support, deciding the appropriate treatment for a patient, comprising personalized medicines, and management of the generated clinical data, using it for subsequent drug development[10] in the future, AI can be used throughout the entire process of creating new drugs from the initial scientific research to make them available to patients. Developed by Eularis, E-VAI is an AI platform designed to support marketing executives in the pharmaceutical industry. With the use of machine learning (ML) techniques and a user-friendly interface, E-VAI makes it easier to analyze competition data, key stakeholder information, and the current market share. This comprehensive analysis empowers executives to optimize resource allocation, reverse declining sales trends, and predict the factors that will drive future success in the pharmaceutical market.[11] With E-VAI, marketing leaders can pinpoint the best investment

opportunities, strategically allocate resources to boost market share, and turn around struggling sales.

AI IMPLEMENTATIONS IN DRUG DISCOVERY AND DEVELOPMENT

There is constant availability of vast volumes of AI and drug discovery data, each with different metrics for drug discovery and advancement. Tools for medication discovery and improvement that are intelligence-driven and human-engineered help to find new compounds, expedite drug approval processes, identify new drugs, and increase productivity in research and development. There are various ways that AI can lower the quantity of conventional drug discovery and improve pipeline failures. Target identification and verification are further advanced by simulated intelligence. This is made possible by genomic data in conjunction with biochemical and histological information. International Business Machines (IBM) Watson discovered five novel RNA-binding proteins that may be relevant candidates for understanding the pathogenesis of amyotrophic lateral sclerosis, an illness that is currently incurable.[12] One important area where AI can be used in medication development is in drug repurposing. For instance, Donner and associates generated a range of joint performance ratings about qualitative representations using the transcriptional information index. This evaluation made evidence of compounds with a shared natural function visible to the public, despite their fundamental diversity, and revealed subtle but useful relationships between atoms.[13] A competitive intelligence (AI) system that forecasts rival actions and confidence levels in vivo can drastically cut down on unnecessary investment. Numerous establishments have achieved this objective. Two programs that attempt to forecast the risks associated with novel synthetic compounds are Detox and Proctor.[14]

APPLICATIONS OF AI

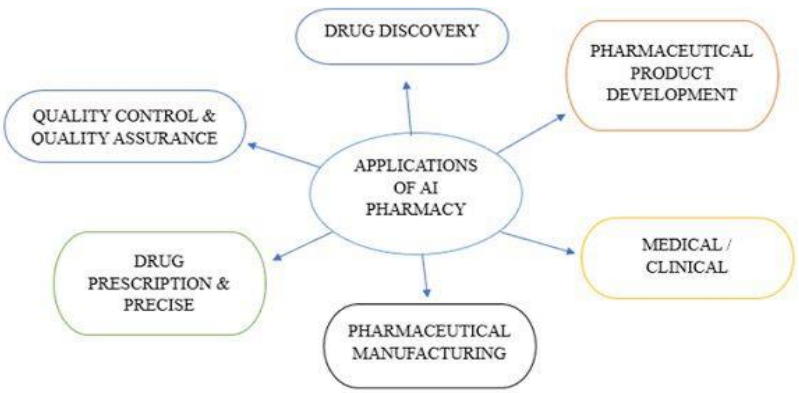

Fig No. 01: Applications of AI In Pharmacy.

AI In Diagnosis and Targeted Genomic Treatments

There are several applications of AI in hospital-based health care systems[15,16] in organizing dosage forms for individualized patients and selecting suitable or available administration routes or treatment policies.

Maintaining of medical records

Maintenance of the medical records of patients is a complicated task. The collection, storage normalizing, and tracing of data are made easy by implementing the AI system. Google Deep Mind health project[17] (developed by Google) assists to excavate the medical records in a short period. Hence, this project is a useful one for better and faster health care. The Moor fields Eye hospital NHS is assisted by this project for the improvement of eye treatment.

Treatment plan designing

The designing of effective treatment plans is possible with the help of AI technology. When any critical condition of a patient arises and the selection of a suitable treatment plan becomes difficult, then the AI system is necessary to control the situation. All the previous data and reports, clinical expertise, etc., are considered in the designing of the treatment plan as suggested by this technology. IBM Watson for Oncology[18], the software as a service, is a cognitive computing decision support system that analyzes patient data against thousands of historical cases and insights gleaned from working thousands of hours with Memorial Sloan Kettering Cancer Center physicians and provides treatment options to help oncology clinicians make informed decisions. These treatment options are supported by literature curated by Memorial Sloan Kettering, and over 300 medical journals and 200 textbooks, resulting in almost 15 million pages of text.[18]

Assisting in repetitive tasks

AI technology also assists in some repetitive tasks, such as examining the X-ray imaging, radiology, ECHO, ECG, etc., for the detection and identification of diseases or disorders. Medical Sieve[19] (an algorithm launched by IBM) is a “cognitive assistant” having good analytical and reasoning abilities. A medical start-up is necessary for the improvement of the patient’s condition by combining deep learning with medical data. A specialized computer program is available for each body part and used in specific disease conditions. Deep learning can be employed for almost all types of imaging analyses, such as X-ray, CT scan, ECHO, ECG, etc.

Health support and medication assistance

In recent years, the uses of AI technology are recognized as efficient in health support services and also, for medication assistance. Molly[20] (a start-up-designed virtual nurse) receives a pleasant voice along with a cordial face. Its aim of it is for helping patients to guide the treatment of patients as well as support them with their chronic conditions during doctor's visits. Ai Cure[21] is an app existing in a Smartphone webcam, which monitors patients and assists them to control their conditions. This app is useful to patients with severe medication situations and for patients who participate in clinical trials.

Accuracy of medicine

AI shows a good impact on genomics and genetic development. Deep Genomics[22], an AI system is useful for observing patterns in the genetic information and medical records to identify the mutations and linkages to diseases. This system informs doctors about the events happening within a cell when DNA is altered by genetic variation. An algorithm is designed by the father of the human genome project, Craig Venter[23] that gives information on patients' physical characteristics based on their DNA. "Human Longevity" AI technology is useful to identify the exact location of cancer and vascular diseases in their early stage.

Drug creation

The development or creation of pharmaceuticals takes more than a decade and consumes billions of rupees. "Atomwise"[24], an AI technology that uses supercomputers, is useful to find out the therapies from the database of molecular structure. It hurled a virtual search program for safe and effective therapy for the Ebola virus with the existing drugs. The technology identified two drugs that caused Ebola infection. This analysis was completed within one day compared to months to years with manual analysis. A Biopharma company in Boston developed big data for the management of patients. It reserves data to find the reasons why some patients survive diseases. They used patients' biological data and AI technology to find out the difference between healthy and disease-friendly atmospheric conditions. It helps in the discovery and design of drugs, healthcare, and problem-solving applications.

AI helps people in the health care system

The "open AI ecosystem"[25] was one of the top 10 promising technologies in 2016. It is useful to collect and compare the data from social awareness algorithms. In the healthcare system, vast information is recorded which includes patient medical history and treatment

data from childhood to that age. This enormous data can be analyzed by the ecosystems and gives suggestions about the lifestyle and habits of the patient.

Healthcare system analysis

In the healthcare system, if all the data is computerized then retrieval of data is easy. Netherland maintains 97% of invoices in digital format[26], which contain treatment data, physician names, and hospital names. Hence, these can be retrieved easily. Zorgprisma Publiek, a local company analyses the invoices with the help of IBM Watson cloud technology. If any mishap occurs, it recognizes it immediately and takes the correct action. Because of this, it improves and avoids patient hospitalization.

AI AND DEVELOPMENT OF PHARMACEUTICALS

Top pharmaceutical companies are collaborating with AI vendors and leveraging AI technology in their manufacturing processes for research and development and overall drug discovery. Reports show nearly 62 percent of healthcare organizations are thinking of investing in AI shortly, and 72 percent of companies believe AI will be crucial to how they do business in the future. To get a better sense of the future of AI in the sector, Pharma News Intelligence[27] dives into current AI use cases, the best uses for the technology, and the future of AI and machine learning. The McKinsey Global Institute estimates that AI and machine learning in the pharmaceutical industry could generate nearly $100B annually across the US healthcare system. According to researchers, the use of these technologies improves decision-making, optimizes innovation, improves the efficiency of research/clinical trials, and creates beneficial new tools for physicians, consumers, insurers, and regulators. Top pharmaceutical companies, including Roche, Pfizer, Merck, AstraZeneca, GSK, Sanofi, AbbVie, Bristol-Myers Squibb, and Johnson & Johnson have already collaborated with or acquired AI technologies. In 2018, the Massachusetts Institute of Technology (MIT) partnered with Novartis and Pfizer to transform the process of drug design and manufacturing with its Machine Learning for Pharmaceutical Discovery and Synthesis Consortium.[27]

Research works are carried out daily to find new active principles for the currently incurable diseases and conditions; increase the safety profile of already existing drugs; combat drug Resistance and minimize therapeutic failure. Hence, there is an increase in the size and variety of biomedical data sets involved in drug design and discovery. This factor and many more contributed to the advancement of AI in the pharmaceutical industry. Today, some

companies offer software with much relevance in drug design and data processing, as well as in predicting treatment outcomes.

GNS healthcare[28] uses AI machine software known as Reverse Engineering and Forward Simulation (REFS). REFS determines the cause and effect relationships between various types of data, that are unforeseen ordinarily by direct data evaluation. GNS claims that REFS can transfer millions of data points ranging from clinical to genetics, laboratory, imaging, drug, consumer, geographic, pharmacy, mobile, proteomic, and so on. In drug design, a company known as Atomwise developed the first deep learning neural network for structure-based drug design and discovery that they called AtomNet.[29] AtomNet makes use of a statistical approach to extract information from millions of experimental affinity measurements and thousands of protein structures to predict the binding properties of small molecules with proteins. By presenting 3-dimensional images of the protein and ligand pair showing channels for carbon, oxygen, nitrogen, and other types of atoms, AtomNet technology enables the pharmaceutical chemists to perform core processes of drug discovery and design like hit discovery, lead optimization, and prediction of toxicity with high precision and accuracy in weeks as against years.

NEED FOR AI IN PHARMACY SYSTEM

While there is a growing interest in the use of AI in pharmacy systems, it is important to note that its implementation should be carefully considered and planned. While AI has the potential to revolutionize the industry by providing personalized medication management and 24/7 support to patients, it is important to ensure that it is used ethically and that potential limitations and challenges are addressed. Therefore, a thoughtful and evidence-based approach is needed to ensure that AI is used effectively and responsibly in the pharmacy system.

The growing population will benefit from the implementation of AI in the pharmacy system as it can help address the increasing demand for healthcare services. With personalized medication management and 24/7 support, AI can help patients manage their medications more effectively, reducing the need for frequent visits to healthcare providers. This can help ease the burden on the healthcare system and improve access to care for patients. Additionally, AI can potentially reduce medication errors and adverse drug interactions, improving patient outcomes and reducing healthcare costs. By improving medication management and reducing the workload on healthcare providers, AI can help address the

challenges associated with the growing population and the increasing demand for healthcare services.

The implementation of AI in the pharmacy system can help make the world a better place in several ways. Firstly, it can improve access to healthcare services by providing personalized medication management and 24/7 support to patients.[30,31] This can help patients manage their medications more effectively and reduce the need for frequent visits to healthcare providers, which can be especially beneficial in areas where healthcare services are limited or inaccessible. Secondly, AI can potentially reduce healthcare costs by minimizing medication errors and preventing adverse drug interactions, resulting in fewer hospitalizations and lower healthcare expenses. Thirdly, AI can reduce the workload on healthcare providers, allowing them to focus on more complex tasks and improving the quality of care they can provide. Overall, the implementation of AI in the pharmacy system has the potential to improve healthcare outcomes, reduce healthcare costs, and increase access to healthcare services, making the world a better place for everyone.[32,33,34]

The use of AI in pharmacy implications shows promise, but there are several research gaps that need to be addressed as shown in Fig No:02. These include patient satisfaction with this technology, long-term outcomes such as the impact on medication adherence, ethical implications such as data privacy and potential biases, technical challenges including data integration and system maintenance, and usability for both patients and pharmacists. By addressing these research gaps, researchers can further understand the implications of using AI in the pharmacy system, develop solutions that maximize its benefits, and mitigate its limitations while ensuring ethical use.

The novelty of a study on the use of AI in the pharmacy system lies in its potential to revolutionize the industry. While there have been previous studies on the use of AI in healthcare, AI is a state-of-the-art AI technology that can generate human-like responses to natural language inputs, allowing patients to communicate with it in a conversational manner. It can help identify the unique challenges and opportunities associated with this technology, including its limitations and ethical concerns. By understanding these challenges, researchers can develop solutions that maximize the benefits of AI while mitigating its limitations and ensuring ethical use.[35,36,37]

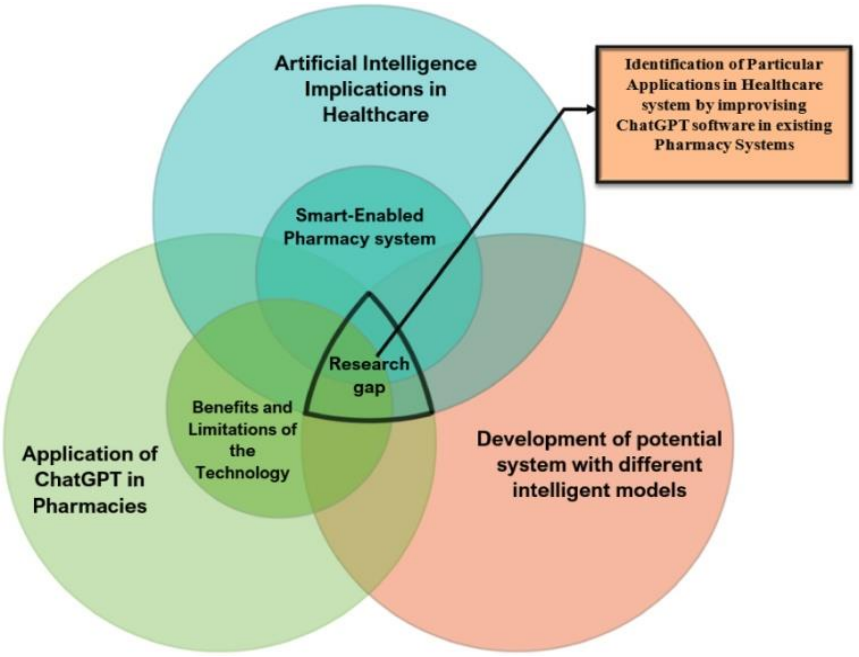

Fig. No. 02: Research gaps and hurdles for intelligent pharmacies.

The objectives of the study are

To evaluate the performance of the new AI-powered pharmacy system in comparison to the old manual pharmacy system.

To assess the impact of the AI-powered pharmacy system on efficiency, patient outcomes, cost savings, and regulatory compliance.

To analyze the feasibility and practicality of implementing the AI-powered pharmacy system in different healthcare settings.

To identify any potential drawbacks or challenges associated with implementing the AI-powered pharmacy system.

To provide recommendations for future research and development of AI-powered pharmacy systems.

HOW BIG PHARMA COMPANIES ARE UTILIZING AI IN DRUG DISCOVERY

The pharmaceutical industry embraces AI as major companies integrate advanced technologies to transform drug discovery, clinical trials, and manufacturing. Fig No: 03 illustrates how leading firms collaborate with AI innovators to improve efficiency, cut costs, and accelerate the development of new therapies. These partnerships drive innovation and address key challenges, including patient recruitment, disease diagnosis, and treatment

accessibility. Companies like Sanofi, Pfizer, and Novartis are at the forefront of this transformation, embedding AI into their core processes.

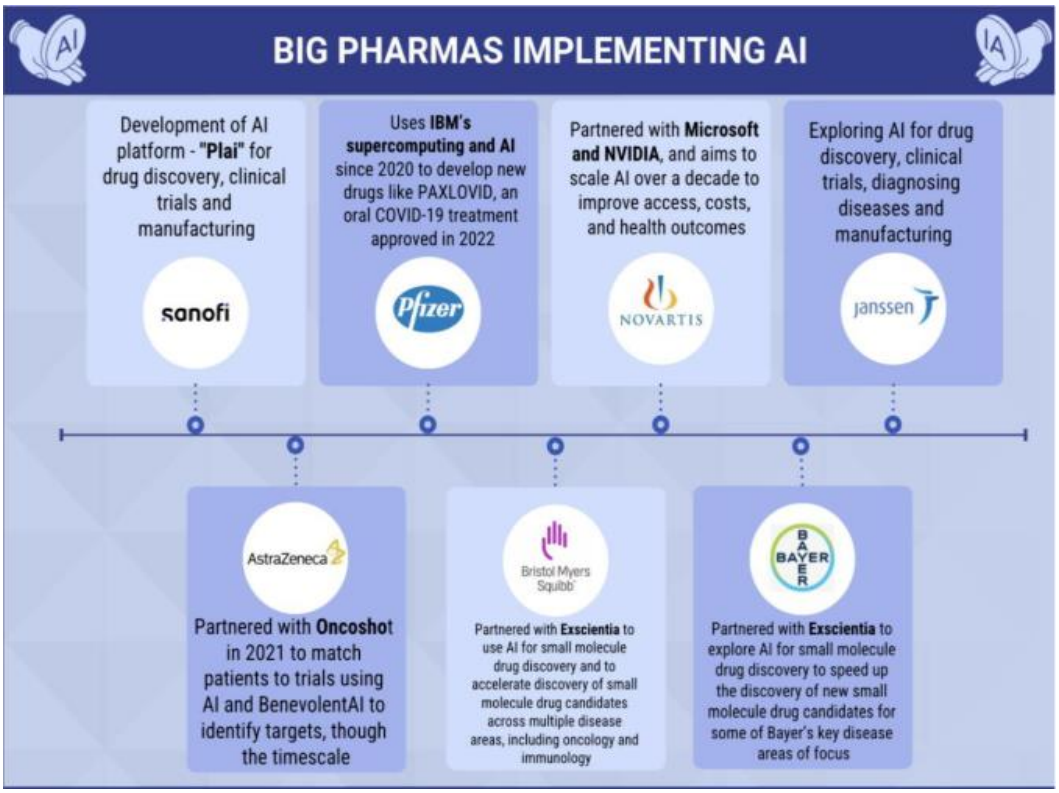

Fig. No: 03. How big pharma companies use AI for drug discovery

From Sanofi's development of the "Plai" AI platform for drug development to Pfizer's use of IBM's AI technology for COVID-19 treatments like Paxlovid, AI is being applied across the pharmaceutical industry in diverse ways. Companies such as AstraZeneca, Bristol Myers Squibb, and Bayer leverage AI for small molecule drug discovery and efficient clinical trial matching. At the same time, Novartis and Janssen focus on improving health outcomes and optimizing manufacturing processes. These collaborations between major pharmaceutical firms and AI innovators highlight the transformative role of AI in developing groundbreaking therapies and fostering a patient-centered approach to healthcare.[38]

AI in Patient Care

AI transforms patient care by enhancing diagnostic accuracy and advancing healthcare outcomes. Using sophisticated algorithms to analyze large datasets, AI enables more precise diagnoses and personalized treatment plans. This integration fosters early disease detection, efficient patient management, and optimized therapeutic strategies, revolutionizing traditional healthcare. Below are key ways AI is driving advancements in patient care.

Enhancing Diagnostic Precision

AI-based tools, particularly in areas such as medical imaging and genomic analysis, outperform traditional diagnostic methods. These systems excel in interpreting medical scans to identify diseases like cancer and heart conditions earlier and more accurately.[39] By reducing the likelihood of human error, AI systems support clinicians in making better-informed decisions, which ultimately leads to improved patient outcomes.[40] This ability to process complex datasets quickly and effectively positions AI as critical in advancing diagnostic practices.

Advancing Personalized Treatments

AI leverages patient-specific information, including genetic data, medical history, and lifestyle details, to create customized treatment plans. This individualized approach enhances the effectiveness of therapies while minimizing side effects, making it easier for patients to adhere to prescribed treatments.[41] Additionally, AI-powered predictive models can identify individuals at high risk for specific illnesses, allowing for preventive measures that promote population health and reduce long-term healthcare costs.[42]

Optimizing Patient Management and Care Outcomes

AI in patient management leverages predictive analytics and real-time monitoring to streamline therapeutic interventions and enhance patient care.[43] AI-driven platforms improve collaboration among healthcare providers, ensuring patients receive consistent and continuous care. This integration reduces diagnostic errors, improves treatment coordination, and enhances health outcomes.[44]

CONCLUSION

AI involves the combination of human knowledge and resources with Artificial Intelligence. As research into AI continues, with many interesting applications of it in progress, one may consider it a necessary evil even for those that see it as an enemy. Therefore, it is strongly recommended that pharmacists should acquire the relevant hard skills that promote AI augmentation. Education about and exposure to AI is necessary throughout all domains of pharmacy practice. Pharmacy students should be introduced to the essentials of data science and fundamentals of AI through a health informatics curriculum during their PharmD education. Pharmacists must also be allowed to develop an understanding of AI through continuing education. Data science courses or pharmacy residencies with a focus on AI topics should be made available for pharmacists seeking more hands-on involvement in AI

development, governance, and use. As these technologies rapidly evolve, the pharmacy education system must remain agile to ensure our profession is equipped to steward these transformations of care.

While the potential applications of AI in pharmacy are vast, there is still much work that needs to be done in terms of research and development. One potential area for future study could be the integration of AI technology with other healthcare systems, such as electronic health records (EHRs) or telmedicine platforms. This could allow for a more comprehensive and coordinated approach to healthcare delivery, improving patient outcomes and reducing healthcare costs. Another area for future research could be the ethical considerations around the use of AI technology in pharmacy. As the technology continues to evolve, it is important to consider issues such as data privacy and security, algorithmic bias, and the potential for AI systems to replace human jobs. Addressing these issues in a thoughtful and proactive manner can help to ensure that the implementation of AI in pharmacy is both effective and ethical. By continuing to explore these areas of study, we can further unlock the potential of AI technology in pharmacy and pave the way for a more efficient and effective healthcare system.

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