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A Review on AI the New Helper in Medicine

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***Abstract*—Artificial Intelligence (AI) is rapidly transforming the field of medicine by supporting healthcare professionals in diagnosis, treatment planning, and research. Rather than replacing human expertise, AI acts as a powerful assistant that enhances accuracy, efficiency, and decision making. From analyzing medical images to predicting disease outcomes and personalizing therapies, AI based systems are proving to be valuable tools in clinical practice. This review highlights the major applications of AI in medicine, its benefits in improving patient care, and the ethical challenges that accompany its use. By understanding both its potential and limitations, we can view AI not as a replacement, but as a new and reliable helper that strengthens modern healthcare.**

***Index Terms*—Artificial Intelligence, Drug Discovery, Pharmacovigilance.**

I. INTRODUCTION

The 21st century is often described as the age of digital revolution, and pharmacy is one of the fields witnessing rapid and meaningful changes.[8] Pharmacy has always been an integral part of healthcare, ensuring that patients receive safe, effective, and high-quality medicines. [5] Traditionally, the focus of pharmacy was mainly on compounding, dispensing, and providing advice about drugs.[5] However, with the rise of artificial intelligence (AI) and digital technologies, the scope of pharmacy has broadened significantly. [4] These innovations are not merely tools that make tasks easier, they are transforming the very nature of how medicines are developed, prescribed, distributed, and monitored.[12] This transformation is often described as "digital transformation in pharmacy," and it has the potential to redefine the role of pharmacists and reshape the healthcare system.[5] Artificial intelligence is one of the most influential forces behind this change. Al refers to computer systems that can mimic human intelligence, including learning, reasoning, and decision-making.[11] In pharmacy and healthcare, Al can analyze vast amounts of data quickly and accurately.[1] For instance, drug discovery-a process that traditionally takes many years and involves huge costs can now be accelerated with the help of Al algorithms. [1] These systems can examine millions of molecular structures, predict how they will interact with the human body, and suggest potential drug candidates in a matter of weeks. [3] This not only speeds up research but also reduces costs, making medicines more affordable in the long run. [4] Digital transformation goes beyond drug discovery. It includes the integration of electronic health records (EHRs), telemedicine, e-pharmacy services, mobile health applications, cloud-based platforms, and wearable devices. [5] All these tools create a connected environment where patients, doctors, and pharmacists can share information easily and make better decisions.[6] For example, a patient's prescription can now be uploaded electronically, reducing the chances of errors due to unclear handwriting.[27]

In recent years, artificial intelligence (AI) and digital technologies have begun transforming almost every aspect of our lives, and pharmacy is no exception. Digital transformation in pharmacy refers to the use of modern tools such as Al, data analytics, mobile health apps, and electronic medical records to improve how medicines are discovered, produced, distributed, and prescribed.[5] This change is not just about machines replacing human effort but about creating a healthcare system that is faster, safer, and more patient centered. [6] Al plays a particularly important role because it can analyze vast amounts of health and drug data in very little time, helping researchers and healthcare professionals make better decisions.[3] In drug discovery, Al can identify new molecules, in hospital pharmacies, it supports inventory management, and in clinical practice, it helps personalize treatments according to individual patient needs.[4] At the same time, digital tools such as e-pharmacy platforms, telemedicine, and health apps are making it easier for patients to access medicines and guidance directly from their homes.[5]

Artificial intelligence itself refers to computer systems designed to think, act, or make decisions in ways similar to human reasoning.[11] Its most widely used form, machine learning, learns from large sets of data to recognize patterns, while deep learning goes even further to analyze complex medical information.[2] These technologies are now applied in areas such as medical imaging, diagnosis, screening, treatment planning, and even personalized healthcare.[14] As a result, pharmacists and healthcare workers are no longer limited to their traditional roles; they are supported by Al systems that reduce errors, save time, and improve patient outcomes.[5] However, even as technology advances, compassion remains central to healthcare.[19] Compassion is the ability to recognize suffering and act to relieve it, and it is essential for building trust, improving patient satisfaction, and ensuring holistic care.[19] The question that arises is: can Al truly support compassionate care?[19] While Al lacks human emotions, it can assist healthcare professionals by reducing workloads, preventing errors, and giving them more time to connect with patients.[5] In this way, Al and digital transformation are not replacing the human touch in pharmacy and healthcare, but rather helping professionals provide safer, faster, and more compassionate services.[5] Dispensing medicines, pharmacists are now becoming active participants in patient-centered care.[5] They can use Al tools to monitor patients' treatment progress, identify possible side effects, and provide personalized advice. Mobile apps and digital reminders are helping patients stick to their medication schedules, while online consultations (telepharmacy) are making it easier for people in remote areas to access expert advice. [5] This shows that technology is not replacing pharmacists, but empowering them to provide safer and more effective care. Another key element of digital transformation is the improvement in patient experience.[5] Patients today expect healthcare to be faster, more accessible, and more personalized. Digital pharmacy services meet this expectation by offering doorstep delivery of medicines, 24/7 access to online consultations, and health apps that track everything from blood pressure to sugar levels. [8] AI-powered chatbots are being used to answer basic medical queries, while wearable devices continuously monitor health indicators and alert doctors or pharmacists when necessary. [22]

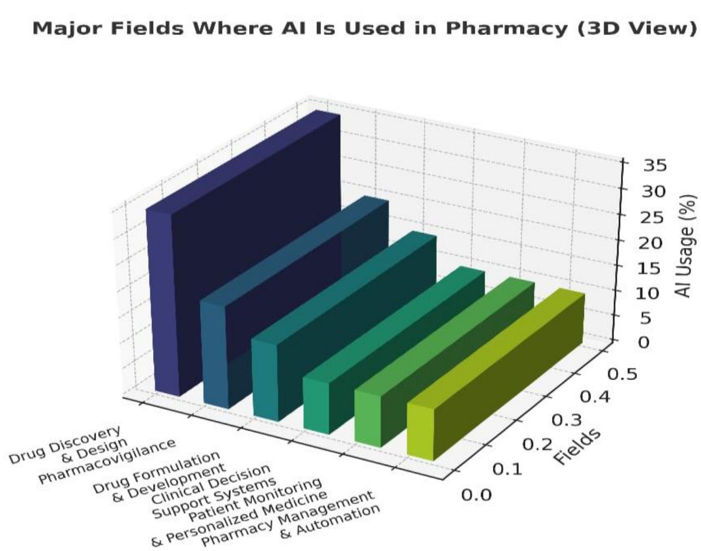

Figure 1.

The graph represents the growing integration of AI in multiple domains of pharmacy.[8] Drug discovery and design remain the leading area, followed by pharmacovigilance and formulation research.[1] AI's role in patient monitoring and pharmacy automation is also increasing rapidly, indicating a shift towards smart and data-driven healthcare systems. [5]

Revolutionizing Pharmacy Marketing with Artificial Intelligence and Machine Learning:
The integration of Artificial Intelligence (AI) and Machine Learning (ML) has transformed the landscape of pharmacy marketing by introducing data-driven precision, personalized outreach, and predictive insights.[6] Traditional marketing strategies in the pharmaceutical sector relied heavily on generalized promotions, in-person visits, and printed materials. [6] However, with the evolution of digital health technologies, AI and ML are now enabling marketers to reach patients and healthcare professionals more effectively and efficiently. [7]

AI tools analyze massive amounts of patient and market data to identify behavioral patterns, preferences, and medication needs.[7] This allows for more personalized marketing campaigns, targeted advertising, and efficient allocation of marketing budgets.[6] Machine learning algorithms also assist in forecasting market trends, optimizing drug pricing, and enhancing the visibility of pharmaceutical brands through predictive analytics.[7]

Chatbots powered by AI are being used to engage customers, answer medicine related queries, and improve customer satisfaction.[21] Furthermore, AI driven social media analytics help marketers understand public sentiment about medicines, health products, and brand reputation in real time.[6] In addition, AI systems support compliance with marketing regulations by automatically screening promotional content for ethical and legal accuracy.[7]

Overall, AI and ML are not only improving how pharmaceutical companies communicate and promote their products but also ensuring that marketing becomes more patient centered, transparent, and cost effective.[6] As technology continues to evolve, the role of AI in pharmacy marketing will expand further leading to smarter, evidence-based strategies that align with the needs of modern healthcare consumers.[7]

II. APPLICATION

1. AI in Drug Discovery:
The process of discovering and developing new drug molecules from the vast chemical space is often time consuming and expensive.[1] Traditional methods depend on trial and error, which can take many years to find an effective and safe drug candidate.[2] Artificial Intelligence (AI) is now helping to speed up this process by using advanced computer algorithms that can predict and analyze chemical and biological data more efficiently.[3]

AI models such as machine learning and deep learning are used to study the quantitative structure activity relationship (QSAR) of molecules. [2] This means AI can predict how changes in a molecule's structure might affect its biological activity, safety, and effectiveness.[1] For example, AI can forecast properties like solubility, lipophilicity (log P or log D), and pharmacokinetics which helps researchers understand how a drug behaves in the body.[4]

By using large databases such as PubChem, ChemBank, DrugBank, and ChemDB, AI can quickly analyze thousands of molecules to find the ones most likely to work as potential drugs. [16] This process, called virtual screening, helps eliminate unsuitable compounds early, saving both time and cost.[13]

AI-based algorithms also consider the physical, chemical, and toxicological characteristics of molecules before choosing the best lead compound.[14] Tools like Simplified Molecular Input Line Entry System (SMILES) and Quantitative Structure Property Relationship (QSPR) models help in predicting binding properties and other key features of the molecule.[12]

In addition, deep learning models and neural networks are being used in programs such as the ADMET predictor and ALOGPS, which estimate important drug parameters like absorption, solubility, and toxicity.[17] These AI tools can process vast amounts of molecular data and identify new chemical entities faster than traditional laboratory methods.[1]

III. AI IN PREDICTION OF BIOACTIVITY AND TOXICITY

The effectiveness of a drug largely depends on how strongly it interacts with its target protein or receptor. [18] Understanding these interactions early is critical for predicting whether a compound will have the desired biological effect. [4] Traditionally, researchers relied on similarity-based approaches, assuming molecules with comparable structures act on similar targets. [2] Tools such as SEA (Similarity Ensemble Approach) and ChemMapper have been used to identify potential drug target interactions by analyzing molecular structures and substructures.[13]

With the rise of deep learning, predictions have become more accurate and faster. [14] Unlike older methods, deep learning can often predict interactions without needing detailed three-dimensional protein structures.[16] Models like DeepAffinity analyze large datasets of molecular and protein features to estimate how likely a drug is to bind to its target, improving efficiency in early drug discovery.[15]

Predicting toxicity is equally important to ensure safety.[18] While laboratory assays and preclinical tests are still standard, AI-based methods now allow researchers to anticipate harmful effects even before experiments begin. [17] For example, the eToxPred tool uses machine learning to estimate potential toxicity of small molecules, while TargeTox evaluates toxicity based on the drug's target proteins.[13] Another useful platform is ProTox-II, which predicts various types of toxicity, including organ specific effects, using chemical structure information.[14]

One practical application is PredTox, which focuses on identifying compounds that may cause drug induced liver injury (DILI).[17] It combines chemical structure analysis with preclinical data to flag risky molecules, helping researchers eliminate unsafe candidates early in the development process.[1] By doing so, PredTox saves time, resources, and reduces the likelihood of failure in clinical trials.[4]

AI also supports structure-based drug design by predicting protein shapes and guiding the selection of promising molecules. [14] Decision support systems powered by AI assist in optimizing formulations and ingredient combinations, while automated platforms like Chemical Assembly help improve manufacturing efficiency without compromising product quality.[12]

IV. CHALLENGES OF AI IN PHARMACY

The investment required for AI technologies including software, hardware, training, and maintenance can potentially limit access for some pharmacies, particularly smaller or resource limited ones. [5] Training and skill gaps are another major challenge.[6] Most pharmacists are not trained in AI, data analytics, or programming, which makes it difficult to implement and utilize these technologies effectively.[5]

Trust and acceptance also pose significant barriers.[6] Both patients and healthcare providers may be apprehensive about AI's capabilities, leading to hesitation in its adoption. [19] For example, while AI can assist in predicting adverse drug reactions or personalizing medication regimens, some patients may prefer human judgment, and some pharmacists may be reluctant to rely on automated recommendations.[5]

Job displacement is another concern.[26] AI-driven automation could reduce the demand for non-specialized pharmacy roles, raising fears of job loss.[5] While AI can streamline routine tasks such as inventory management or prescription validation, it may shift the workforce toward more specialized or tech-oriented roles.[6]

Regulatory constraints also affect AI in pharmacy. [24] Rules for safety, transparency, and fairness directly influence the development, deployment, and implementation of AI solutions.[25] Compliance with these regulations can be complex, slowing down adoption.[27]

Data privacy and security remain critical challenges.[27] Pharmaceutical data is highly sensitive, and protecting patient information from breaches, unauthorized access, or misuse is essential.[24] Additionally, AI models require high quality datasets.[4] However, obtaining large, consistent, and well-integrated datasets is difficult due to data heterogeneity and inconsistencies, which can impact model accuracy.[12]

Bias is a major concern.[5] Even with accurate and representative data, AI systems may reflect underlying inequities in the healthcare system.[24] For instance, if AI models are trained primarily on data from urban populations, predictions for rural patients may be less accurate, potentially leading to disparities in care.[19]

Challenges to Future Scope: Laws, Ethics, and Regulatory Considerations
1. General AI & Data Protection Laws

Data Privacy (HIPAA in the US, GDPR in the EU, PDPA in some countries):
AI systems in pharmacy often process sensitive patient health information[27]. These laws ensure that patient data is protected, requiring transparency, informed consent, and robust safeguards in AI-driven pharmacy applications[24]. For example, AI tools predicting adverse drug reactions must maintain strict confidentiality of patient records[24].

AI Specific Regulations (EU AI Act, emerging US frameworks):
AI used in healthcare is increasingly classified as "high risk"[24]. Regulations mandate risk assessments, human oversight, and monitoring for bias[25]. This ensures that AI tools supporting pharmacists, such as automated dosage calculators or prescription verification systems, remain safe and reliable[27].

Emerging Laws & Trends: AI in Pharmacovigilance:
Legal frameworks are evolving to allow AI assisted monitoring of adverse drug reactions (ADRs), enhancing patient safety while complying with regulatory requirements[5].

Liability Laws:
Determining responsibility for errors made by AI whether in dispensing, dosing, or drug recommendations is critical. Accountability may involve the pharmacist, healthcare institution, AI developer, or manufacturer[5].

Intellectual Property (IP):
Patent laws are adapting to accommodate AI generated innovations, such as novel drug formulations or predictive algorithms for personalized medicine[15].

2. Ethical & Professional Guidelines
Accountability: Pharmacists remain legally responsible for patient outcomes, even when AI provides recommendations, reinforcing the role of AI as a supportive tool rather than a replacement[24].

Transparency: AI-driven tools, like drug interaction checkers or dosage calculators, must be explainable to healthcare providers to ensure informed clinical decisions[5].

Bias & Fairness: AI systems must avoid discriminatory outputs that could affect access to medications or treatments, ensuring equitable patient care[19].

3. Pharmacy Practice & Drug Safety Regulations
Regulatory Agencies (FDA in the US, EMA in Europe, CDSCO in India, MHRA in the UK): AI algorithms used in drug design, clinical trials, or pharmacy automation may require regulatory approval, particularly if they influence medication dispensing or dosage adjustments[25]. Some AI tools may be classified as Software as a Medical Device (SaMD)[24].

Advantages and Opportunities
AI accelerates drug discovery by analyzing massive datasets to identify potential drug candidates, predict efficacy, interactions, and side effects, significantly reducing the time and cost of clinical trials[1]. In personalized medicine, AI integrates patient genetics, lifestyle, and clinical history to optimize drug selection and dosage, improving treatment outcomes[24]. Pharmacy operations benefit from robotic dispensing, AI driven inventory management, and digital workflows, which reduce human errors and streamline prescription processing[5].

Clinical decision support systems leverage AI to detect drug drug interactions, contraindications, and allergies in real time, providing evidence-based recommendations to pharmacists and enhancing patient safety[14]. Telepharmacy platforms and AI powered chatbots expand access to remote counseling, particularly in rural or underserved areas[22]. AI also improves medication adherence through smart pillboxes and mobile applications that track patient compliance and alert healthcare providers to non adherence[6]. Integration with electronic health records ensures accurate e-prescribing, reduces prescription errors, and strengthens communication among pharmacists, physicians, and patients[5].

In pharmacovigilance, AI scans adverse event reports, medical literature, and patient data to identify safety risks promptly, enabling timely interventions[5]. Supply chain management is optimized through predictive analytics and blockchain technology to ensure drug authenticity, prevent counterfeiting, and maintain cold chain integrity for sensitive medications[25]. Finally, AI and virtual reality simulations enhance education and continuous professional development, allowing pharmacy students and practicing pharmacists to improve dispensing skills and patient interactions while minimizing errors[11].

V. LIMITATIONS

Despite its advantages, AI in pharmacy faces multiple challenges [5].High implementation costs for AI systems, robotics, and digital infrastructure may limit access, particularly for smaller or rural pharmacies[5]. Training and adaptation remain hurdles, as pharmacists and staff require digital literacy and technical skills, and resistance to change can slow adoption[6]. Automation also raises concerns about job displacement, particularly in routine pharmacy roles[26].

Data privacy and security are critical issues, as patient information is highly sensitive and vulnerable to breaches, requiring strict compliance with HIPAA, GDPR, and national regulations [27]. Ethical and legal uncertainties persist regarding responsibility for AI driven errors in medication dispensing or dosing, which may involve pharmacists, software developers, or healthcare institutions [24]. Overreliance on AI may diminish human judgment and personalized care[19], while interoperability challenges between EHRs, prescription software, and AI platforms can cause errors, duplication, or delays[12]. Furthermore, AI algorithms may generate inaccurate outputs if trained on biased, incomplete, or inconsistent datasets, highlighting the need for continuous validation and monitoring[4].

VI. CONCLUSION

Artificial intelligence (AI) is rapidly transforming medicine and pharmacy by enhancing drug discovery, predicting bioactivity and toxicity, supporting personalized treatment, and optimizing pharmacy operations[1]. In drug discovery, AI accelerates target identification, compound screening, and lead optimization, enabling the development of novel therapeutics more efficiently and with reduced costs[3]. Machine learning models also improve the prediction of bioactivity and potential toxicity, minimizing risks in preclinical research and guiding safer drug design[17].

In clinical practice, AI facilitates personalized medicine and pharmacogenomics, helping healthcare providers tailor treatments based on genetic profiles, comorbidities, and other patient specific factors[24]. Pharmacovigilance benefits from AI through early detection of adverse drug reactions, enhancing patient safety and regulatory compliance[5]. AI applications in microbiology, including antimicrobial resistance prediction and vaccine development, further demonstrate its transformative potential[25].

Beyond research and clinical care, AI optimizes pharmacy operations and drug distribution[5]. Predictive analytics support efficient inventory management, mitigate drug shortages, and enable targeted patient engagement through personalized marketing strategies[7]. Integration with emerging technologies, such as natural language processing and wearable devices, promises even more personalized and effective healthcare delivery[22].

Despite these advances, challenges remain[5]. High quality data, regulatory acceptance, ethical considerations, and model transparency are critical for reliable AI adoption[24]. Ensuring that AI complements human decision-making, rather than replacing it, is essential to build trust among clinicians and patients[19].

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