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Artificial Intelligence (AI) in Pharmacy

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Abstract- Artificial Intelligence (AI) has emerged as a transformative technology in the pharmaceutical and healthcare sectors, offering significant improvements in efficiency, accuracy, and patient outcomes. This review explores the current and future applications of AI in pharmacy practice, drug discovery, and healthcare delivery. By leveraging machine learning, deep learning, and automation, AI enables the analysis of vast datasets to accelerate drug development, optimize clinical trials, and personalize treatment plans. The article highlights key AI tools, including robotic pharmacy systems for automated dispensing and AI-driven diagnostic models in radiology, cardiology, and ophthalmology. Furthermore, it examines the evolving role of pharmacists, who are shifting from routine dispensing tasks to patient-centric clinical services supported by predictive analytics. While AI presents immense opportunities to reduce medication errors and operational costs, challenges such as data privacy, algorithmic bias, and the need for regulatory frameworks remain. The review concludes that the integration of AI is not merely an enhancement but a fundamental reshaping of pharmacy practice, necessitating new educational curricula and hybrid workflows where human expertise complements computational intelligence.

Index- Terms: Artificial Intelligence, Pharmacy Practice, Drug Discovery, Machine Learning, Healthcare Automation, Personalized Medicine

I.INTRODUCTION

Artificial intelligence is a scientific field focused on creating machines and software capable of performing tasks that typically require human cognitive abilities [1]. It involves gathering information, designing systems that can process and learn from this information, and generating reasoned conclusions while continuously improving through feedback and adjustments [2].
Overall, AI supports machine learning methods that replicate how people think, analyze, and solve problems. By applying advanced statistical techniques and computational intelligence, AI enables more precise assessments and more meaningful interpretations of data [2,3]. As a result, it has become an essential technology for developing highly efficient and adaptable analytical systems

[3].
Pharmacies, if properly equipped, have the potential to evolve into health management centers rather than mere medication fulfillment locations [4,5]. Recent years have witnessed an exponential increase in the pharmaceutical industry's data digitization [6,7]. AI technologies are now widely applied to support the gathering, interpretation, and practical use of information, helping clinicians manage challenging medical problems more effectively. AI provides an efficient means of handling vast amounts of data more effectively, with automation playing an essential part [8,9]. This technology in pharmacy practice has witnessed rapid development over the years, providing the advantages of time and cost savings, as well as simplifying various pharmaceutical tasks [10]. McKinsey Global Institute estimates that AI tools in the pharmaceutical sector may generate over $100 billion annually within the US healthcare system [11].

It is anticipated that AI tools hold immense promise to revolutionize various aspects of pharmacy practice, namely drug supply chain, safety, medication management, and patient care [12].
Chatbots can engage users in a helpful, conversational manner, offering guidance, responding to queries, and addressing concerns. If there's a particularly challenging question, they can seamlessly hand it over to a human team member for a personal touch. Walgreens collaboration with telehealth company Medline to provide patients with video chats with medical professionals is another illustration [13]. For retail pharmacists, AI can simplify stock control by predicting upcoming medication needs, ensuring shelves are prepared, and notifying patients with timely, supportive reminders. AI-driven data analytics can forecast a patient's medication needs, guiding smart inventory choices [11]. Therefore, by active implementation of AI tools into pharmacy practice, pharmacists can shift their focus towards a more patient-centric approach, rather than solely concentrating on prescription dispensing [11]. Additionally, pharmacists can assist individuals in optimizing the benefits of their medications, maintaining better overall health and reducing costs.

II. MATERIALS AND METHODS

This review article provides a comprehensive overview of the role of Artificial Intelligence (AI) in the pharmaceutical and healthcare sectors. A systematic literature search was conducted to gather relevant data regarding the applications, benefits, and challenges of Al integration in pharmacy practice. Electronic databases, including Google Scholar, PubMed, ScienceDirect, and official pharmaceutical reports, were utilized to identify peer-reviewed articles, clinical studies, and review papers.

The search strategy focused on key terms such as “Artificial Intelligence,” “Machine Learning,” “Drug Discovery,” “Pharmacy Automation,” “Robotic Pharmacy,” and “Personalized Medicine.” The selection criteria prioritized literature published primarily within the last decade to ensure the inclusion of the most recent technological advancements and current regulatory perspectives. Information regarding specific AI tools (e.g., IBM Watson, AtomNet) and their applications in various medical fields (radiology, cardiology, ophthalmology) was categorized and analyzed to evaluate the transformative impact of these technologies on patient care and operational efficiency.

III. DRUG DISCOVERY BY ARTIFICIAL INTELLIGENCE

It might take a long time to test a chemical against sick cell samples in drug research. Finding chemicals that are physiologically active and worthy of future investigation necessitates more research. Using photos from machine learning algorithms, Novartis researchers are able to determine which untested chemicals are likely to be worth further investigation [15-18]. When novel and effective medications are discovered faster using computers than with traditional human analysis and laboratory experimentation, the expenses associated with manual examination of each chemical are reduced. The leading biopharmaceutical firms are now working on an AI project that includes:

• Health outcomes: Can be improved using a mobile platform. Real time data collecting enables doctors to propose patients and thereby enhance patient outcomes [19-22].

• Drug discovery: In the time-consuming and expensive process of drug discovery, pharmaceutical corporations are collaborating with software businesses to deploy the most cutting-edge technology [23].

III.1. Medicine and Care

Artificial Intelligence (AI) offers significant potential in healthcare, where there is a shortage of competent employees. As of this writing, four applications have been deemed most promising: Years of medical training are needed to appropriately detect diseases. Diagnosis can be a lengthy and time-consuming procedure even after training has been finished [24-26]. Due to an ongoing labor crunch, the demand for professionals typically outpaces the supply in this industry. Deep learning algorithms, in particular, have made significant advancements in the field of autonomous disease diagnosis in the last few years. Artificial intelligence (AI) has the ability to reduce the cost and increase the accessibility of diagnostics [27-29].

III.2. Drug Development

The development of new drugs is a very expensive and lengthy process. Many of the analytical processes, especially in the early stages of drug development, can be shortened by machine learning. This offers drug manufacturers the opportunity to save years of work and millions in investments. AI is already being used successfully in all four stages of drug development [30- 32]:

1. Identification of intervention goals.

2. Identification of suitable patients for the drugs.

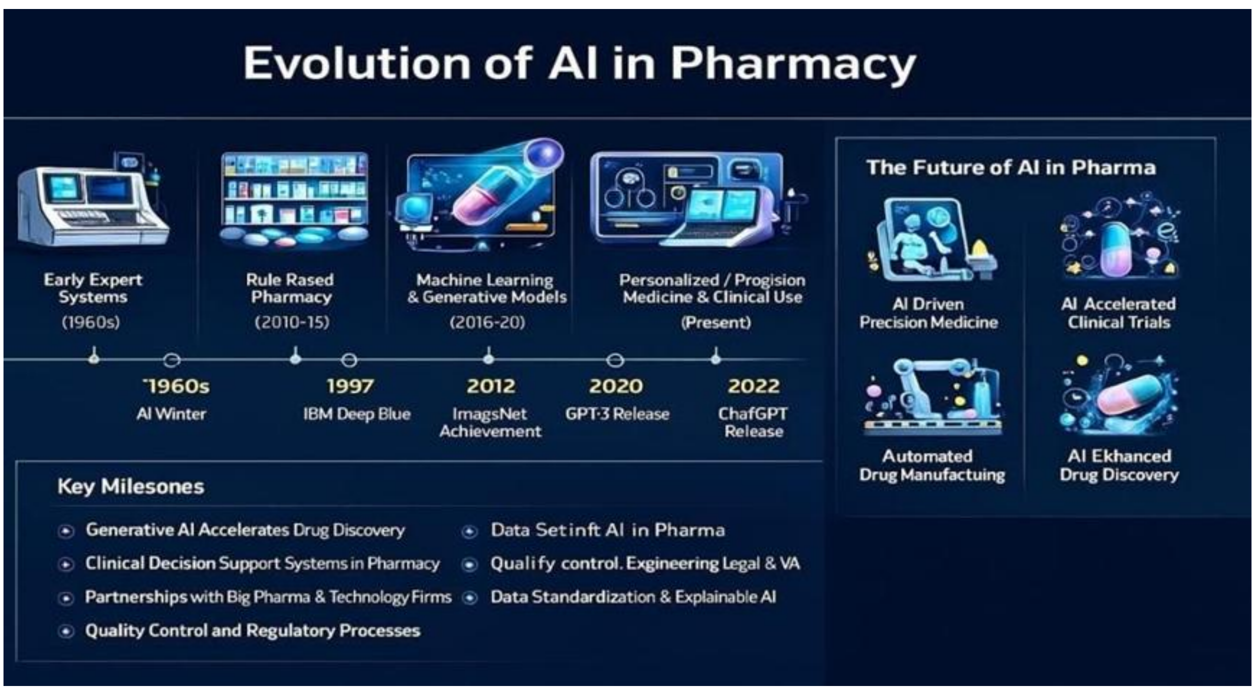
3. Accelerating clinical trials.

4. Identification of biomarkers for the diagnosis of the disease [33-36].

IV. HOW AI IS CHANGING THE PHARMACEUTICAL INDUSTRY

The pharmaceutical field ranks among the world's most tightly controlled and regulated industries. This is mainly because the products pharmaceutical companies make can have a major impact on public health. As such, the industry has historically relied heavily on human judgment and experience to decide which drugs to develop and bring to market [37]. However, with the advent of artificial intelligence (AI), the pharmaceutical industry is beginning to recognize the potential of using AI to assist with some of the routine tasks involved in drug development and commercialization.

For example, AI can be used to analyze data to identify new drug targets or to plan clinical trials. AI can also be used in the development of marketing collateral and in nurturing customer relationships [38]. There are several reasons why AI is well suited for such tasks. First, AI is good at handling large amounts of data. This is important in the pharmaceutical industry, where there is a lot of data to analyze in order to make informed decisions. Second, AI is good at performing repetitive tasks quickly and accurately [39]. Overall, AI is starting to play an important role in the pharmaceutical industry and is likely to become even more important in the coming years.



[FIG. Evolution of AI in Pharmacy]

V. AI AND DEVELOPMENT OF PHARMACEUTICALS

Leading pharmaceutical firms are working with AI suppliers and utilizing AI technology in their production processes for R&D and general drug discovery [41-47]. Recent studies indicate that around 62 percent of healthcare organizations are considering investing in AI soon, while 72

percent view it as essential for future operations. Insights from Pharma News Intelligence provide further perspective on how AI is expected to shape the industry moving forward [48].
Current applications of AI in the pharmaceutical industry include enhancing decision-making, optimizing innovation, and improving research and clinical trial efficiency. The McKinsey Global Institute estimates that AI and machine learning could contribute nearly $100 billion annually to the U.S. healthcare system. These technologies also support the creation of valuable tools for physicians, patients, insurers, and regulators. Leading pharmaceutical companies such as Roche, Pfizer, Merck, AstraZeneca, GSK, Sanofi, AbbVie, Bristol-Myers Squibb, and Johnson & Johnson have already integrated or partnered with AI solutions. In 2018, MIT collaborated with Novartis and Pfizer to advance drug design and manufacturing through its Machine Learning for Pharmaceutical Discovery initiative, demonstrating the transformative potential of AI in pharmaceutical development [48].

Ongoing research continuously seeks new active compounds for diseases currently without cures, improves the safety of existing medications, addresses drug resistance, and reduces treatment failures. As a result, the volume and diversity of biomedical data used in drug discovery and development have grown significantly. These factors have played a major role in advancing AI applications within the pharmaceutical sector. Nowadays, various companies provide advanced software tools that support drug design, data analysis, and the prediction of patient treatment responses, enhancing the overall drug development process.

GNS Healthcare [49] employs AI-driven software called Reverse Engineering and Forward Simulation (REFS) to analyze complex data. REFS identifies cause-and-effect connections among diverse data types that are often overlooked by conventional analysis. According to GNS Healthcare, REFS can handle millions of data points spanning clinical, genetic, laboratory, imaging, pharmaceutical, consumer, geographic, mobile, and proteomic information. In the realm of drug development, Atomwise introduced AtomNet, the first deep learning neural network specifically designed for structure-based drug discovery and design [50]. AtomNet employs a statistical methodology to analyze millions of experimental binding measurements and thousands of protein structures to forecast how small molecules interact with proteins. By generating 3D visualizations of protein-ligand pairs, highlighting channels for atoms like carbon, oxygen, and nitrogen, AtomNet allows pharmaceutical chemists to efficiently carry out critical drug discovery tasks. Processes such as hit identification, lead optimization, and toxicity prediction can be completed with high accuracy and precision in weeks, significantly reducing the timeline compared to traditional multi-year approaches.
Insilico Medicine announced an AI project by the company called Pharm AI. Insilico Medicine reports using Generative Adversarial Networks (GANs) along with reinforcement learning algorithms. GANs are generative models capable of producing new data while learning from existing datasets. They consist of two neural networks: a generator, which creates new samples, and a discriminator, which evaluates them as real or fake. Through iterative training, the generator

improves at producing realistic samples, while the discriminator becomes better at distinguishing them. Using Pharm AI, Insilico Medicine claims to generate novel molecular structures and explore the biological origins of diseases.

VI. TOOLS OF AI

VI.1. IBM Watson for Oncology

IBM Watson for Oncology (WFO) is a cognitive-computing system developed by IBM in collaboration with Memorial Sloan Kettering Cancer Center. It applies natural language processing (NLP) and machine-learning algorithms to process massive volumes of structured and unstructured clinical data including patient records, medical literature, and clinical trial information in order to suggest personalized, evidence-based cancer treatment options [51].
WFO ranks proposed treatment strategies as "recommended," "for consideration," or "not recommended," providing justification and citations to medical studies and guidelines for each suggestion [52].

VI.2. Robot Pharmacy

Robot pharmacy systems are automated machines designed to handle the dispensing, packaging, and storage of medications in hospitals and retail pharmacies. They reduce human errors, improve accuracy, and save time for pharmacists, allowing them to focus more on patient care. These robots can manage high volumes of prescriptions efficiently and integrate with pharmacy management software for inventory control and workflow optimization [53-54].

VI.3. MEDI Robot

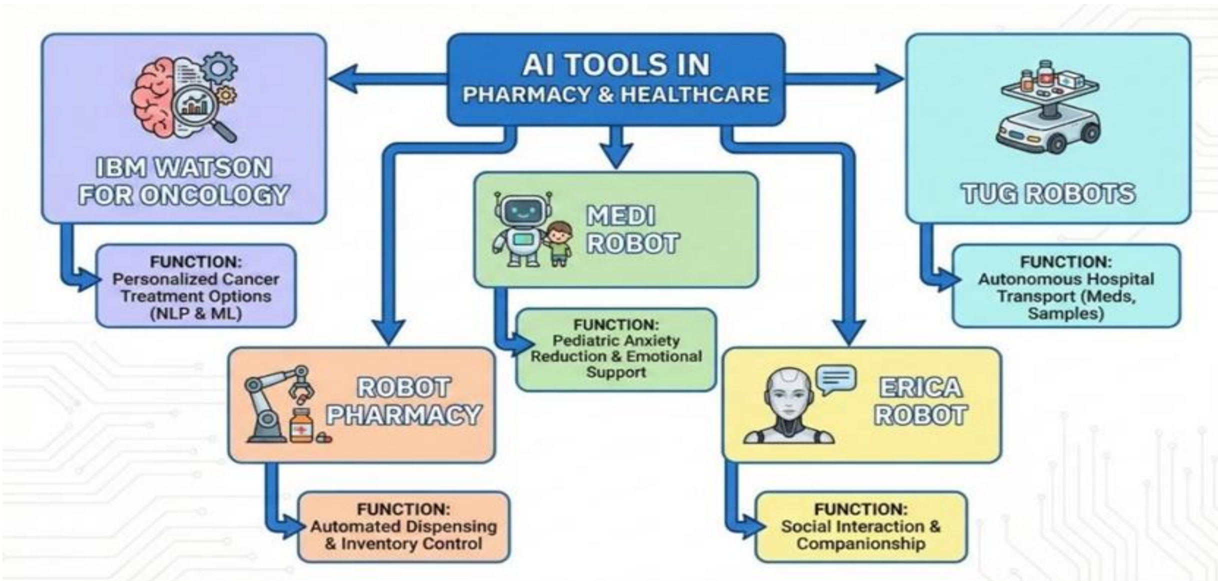
The MEDI robot is a child-friendly social robot used in healthcare settings to reduce anxiety during medical procedures. It uses AI-based interaction, such as talking, playing, and guiding children, to provide emotional support. MEDi helps improve cooperation, lowers stress, and creates a more positive experience for young patients during injections, tests, or hospital visits [55-56].

VI.4. Erica Robot

ERICA is an advanced humanoid robot developed in Japan to interact socially using artificial intelligence. It can recognize speech, respond naturally in conversation, display facial expressions, and maintain eye contact. In healthcare and elder-care environments, ERICA is used to provide companionship, reduce patient loneliness, and support communication for individuals who may benefit from social interaction with an intelligent robot [57-58].

VI.5. TUG Robots

The TUG robot is an autonomous mobile robot used in hospitals to transport medications, laboratory samples, meals, and supplies. Using AI-based navigation and sensors, it moves safely through hallways, avoids obstacles, and delivers items to designated locations. By handling routine delivery tasks, TUG helps reduce staff workload and allows healthcare workers to focus more on direct patient care [59-60].

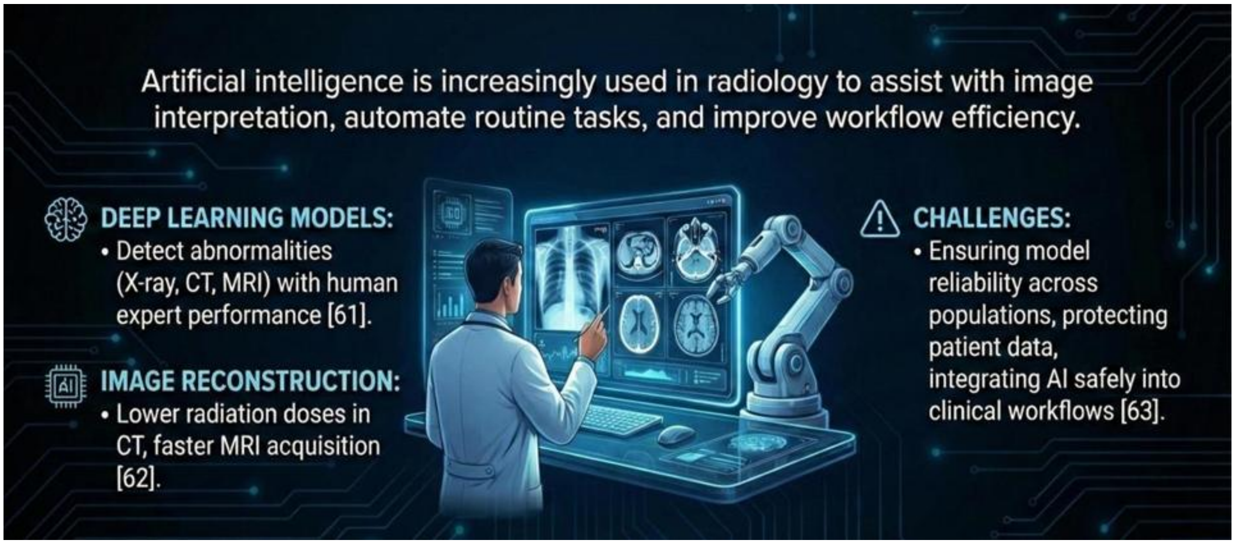


[FIG. TOOLS OF AI]

VII. ARTIFICIAL INTELLIGENCE IN VARIOUS FIELDS OF HEALTH CARE

VII.1. AI in Radiology

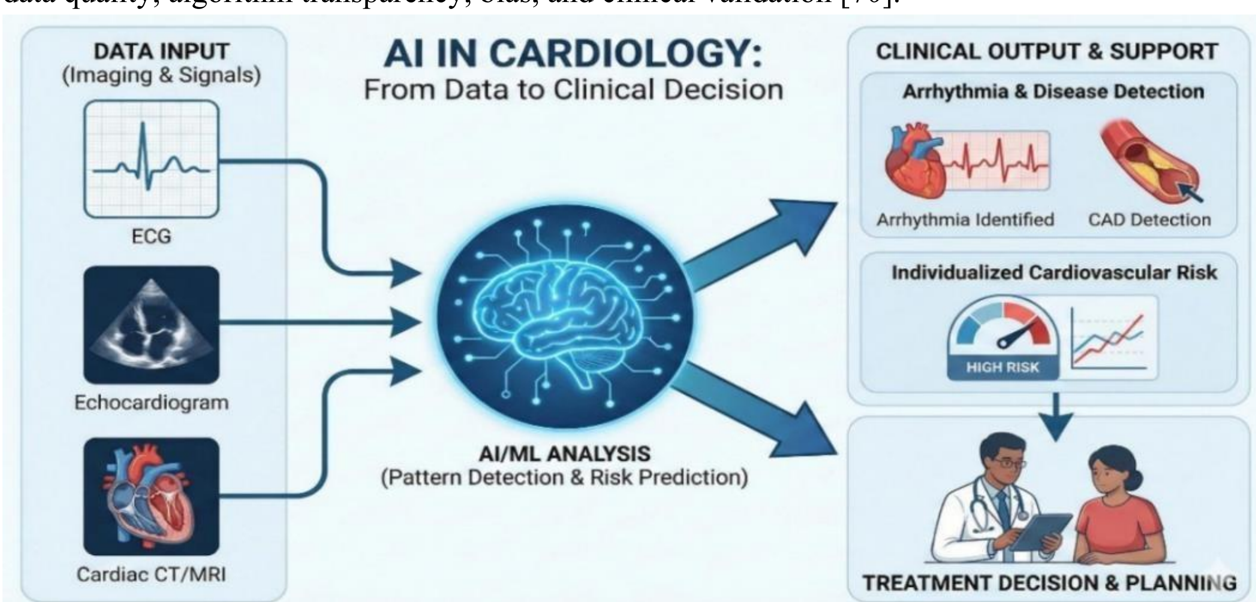
Artificial intelligence is increasingly used in radiology to assist with image interpretation, automate routine tasks, and improve workflow efficiency. Deep learning models, especially convolutional neural networks, can detect abnormalities on X-ray, CT, and MRI scans with performance approaching that of human experts [61]. AI also supports image reconstruction, enabling lower radiation doses in CT and faster MRI acquisition [62]. While these tools can enhance accuracy and reduce reporting time, challenges include ensuring model reliability across different populations, protecting patient data, and integrating AI safely into clinical workflows [63].



[FIG : AI in Radiology]

VII.2. AI in Cardiology

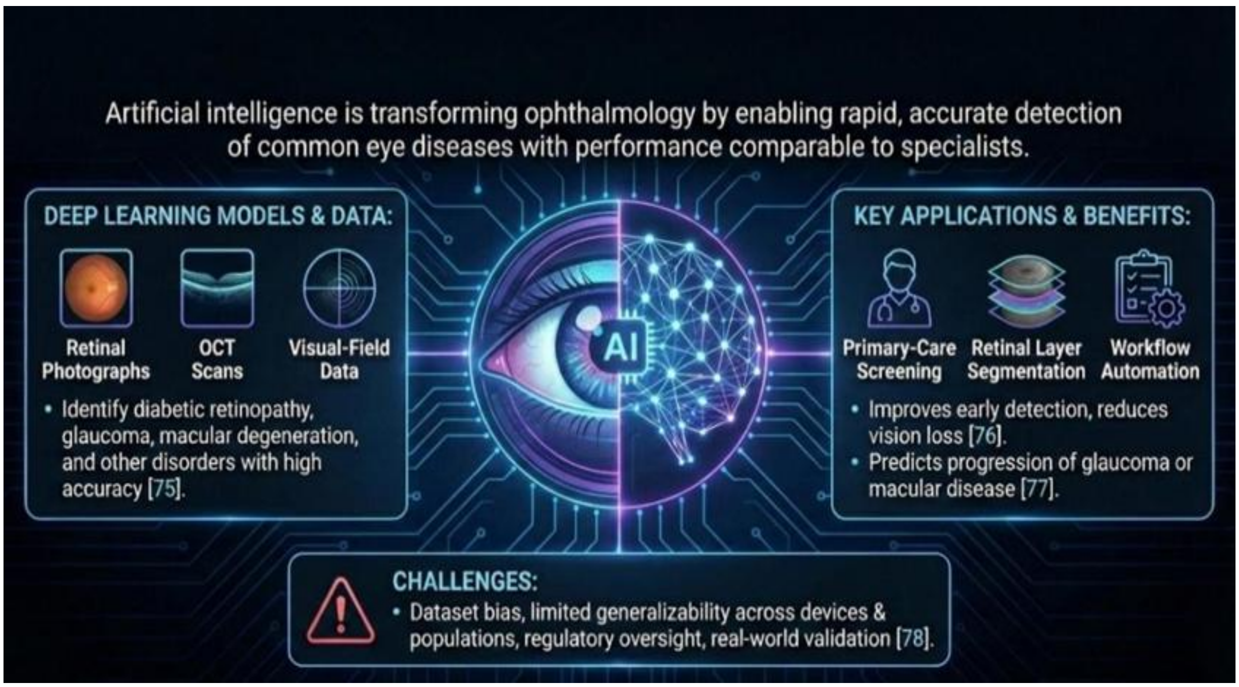
Artificial intelligence is increasingly used in cardiology to improve diagnosis, risk prediction, and treatment decisions [64-65]. Machine-learning models can analyze ECGs, echocardiograms, cardiac CT, and MRI to detect subtle patterns not easily recognized by clinicians [66-68]. Deep-learning systems have shown high accuracy in identifying arrhythmias, predicting heart failure decompensation, and detecting coronary artery disease from imaging [69]. AI-enabled clinical decision support tools can integrate electronic health-record data to estimate individualized cardiovascular risk and guide therapy selection. Although promising, challenges remain related to data quality, algorithm transparency, bias, and clinical validation [70].



[FIG. AI in Cardiology]

VII.3. AI in Ophthalmology

Artificial intelligence is transforming ophthalmology by enabling rapid, accurate detection of common eye diseases [71-74]. Deep-learning algorithms can analyze retinal photographs, OCT scans, and visual-field data to identify diabetic retinopathy, glaucoma, macular degeneration, and other disorders with performance comparable to specialists [75]. AI systems support screening in primary-care settings, improving early detection and reducing preventable vision loss [76]. They also assist clinicians by segmenting retinal layers, predicting progression of glaucoma or macular disease, and automating workflow tasks [77]. Despite major advances, challenges include dataset bias, limited generalizability across imaging devices and populations, and the need for regulatory oversight and real-world validation [78].



[FIG. AI in Ophthalmology]

VIII. APPLICATIONS OF AI IN PHARMACY

AI applications for targeted genomic therapies and diagnosis are used in hospital-based health care systems in a number of ways, including choosing appropriate or accessible administration routes or treatment strategies, as well as structuring dosage forms for specific patients [79,80].

• Maintaining of medical records: Maintenance of the medical records of patients is a complicated task. The AI system makes data collection, storage, normalization, and tracking simple. Google's Deep Mind health project [81] helps quickly uncover medical records. Therefore, this project is beneficial for quicker and better health care.

• Creating treatment plans: AI technology makes it feasible to create efficient treatment plans. An AI system is required to manage the situation when a patient's severe condition develops and choosing an appropriate treatment strategy becomes challenging. The treatment plan that this technology suggests is designed taking into account all of the prior data and reports, clinical competence, etc. IBM Watson for Oncology [82] is a cognitive computing decision assistance system that compares patient data to thousands of historical cases and insights gained by working with Memorial Sloan Kettering Cancer Center physicians.

• Helping with repetitive work: AI technology also helps with certain repetitive chores, such as analyzing radiology, X-ray imaging, ECHO, ECG, and other data for the purpose of identifying and detecting illnesses or problems. Medical Sieve [83], an algorithm developed by IBM, is a cognitive assistant with strong reasoning and analytical skills.

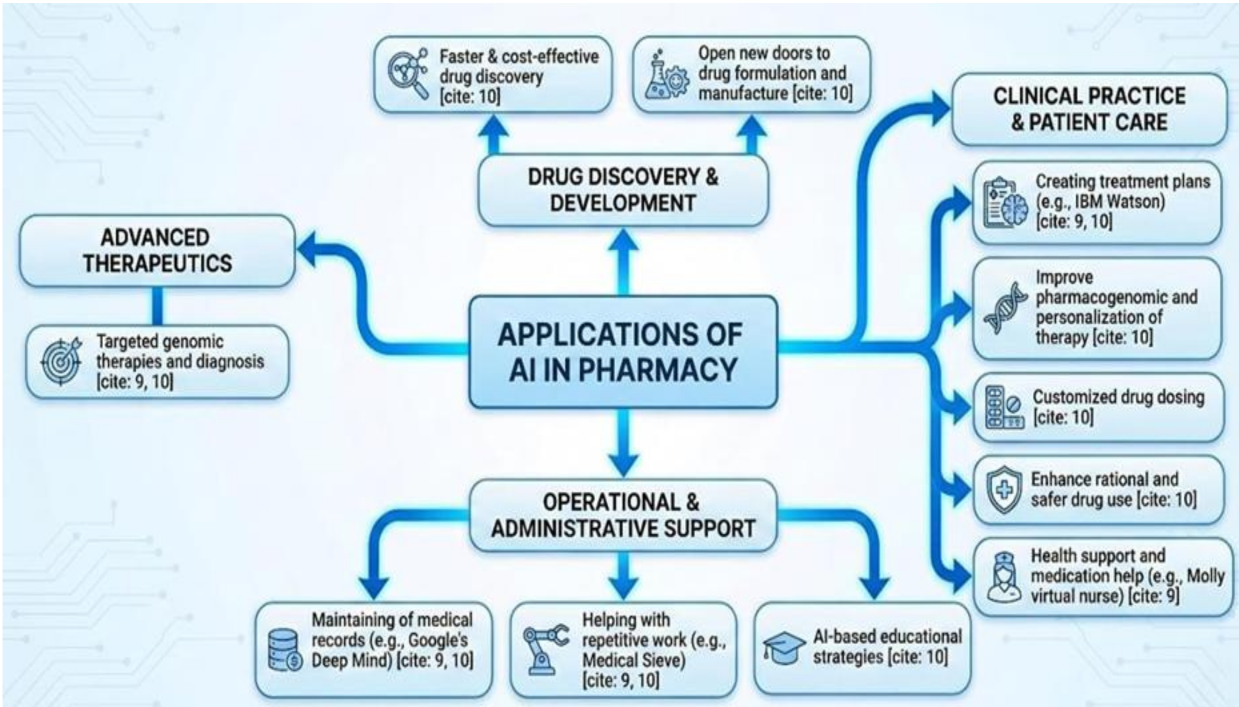
• Health support and medication help: AI technology has been acknowledged as being effective for both medication assistance and health support services. Molly [84], a virtual nurse created by a start-up, is given a friendly face and a charming voice. Its goal is to support patients with their chronic ailments during doctor's appointments and assist them in directing their own treatment. A smartphone webcam app called AiCure [85] keeps track of patients and helps them manage their diseases.

• Medical accuracy: AI has a positive effect on genetic development and genomics. An AI system called Deep Genomics [86] can be used to find mutations and connections to diseases by looking for patterns in genomic data and medical records.

• Drug development: It takes over ten years and billions of rupees to develop or create pharmaceuticals. An AI tool called Atomwise [88] that makes use of supercomputers is helpful in determining the treatments from the molecular structure database. It launched an online search for a safe and efficient Ebola virus treatment using currently available medications.

• AI benefits people in the healthcare system: One of the top ten potential technologies in 2016 was the "open AI ecosystem" [89]. Data from social awareness algorithms can be gathered and compared for usefulness. Ecosystems can analyze this vast amount of data and provide recommendations regarding the patient's behaviors and way of life.

• Analysis of the healthcare system: If all of the data is digitized, data retrieval is simple. 97% of bills in the Netherlands are kept in digital format [90], and they include hospital names, doctor names, and treatment information. As a result, these are easily retrievable.



[Fig. Application Of Ai In Pharmacy]

IX. FUTURE DIRECTIONS

1. Faster, more predictive drug discovery and preclinical design: AI will increasingly act as a front-end research partner that shortens lead discovery, predicts ADMET earlier, and proposes optimised molecular structures for synthesis. Advances in large-scale molecular models, multimodal datasets and massively parallel compute are already allowing companies and consortia to reduce iteration cycles from months to weeks in early discovery [91].

2. Integrated clinical trial design and trial optimisation: Machine learning will improve trial cohort selection, adaptive trial arms, and real-time safety monitoring to reduce trial failure rates and shorten timelines. Federated learning and privacy-preserving model training will let industry and academia share model insights without exposing raw patient data [92].

3. Precision therapeutics and dosing support at the point of care: AI models that combine EHR data, genomics, population pharmacokinetics, and wearable signals will enable individualized drug choice and dosing. These tools will be delivered as clinical decision support integrated into pharmacy information systems and electronic prescribing workflows, with pharmacists as interpreters and safety gates [93].

4. Enhanced medication safety, pharmacovigilance and predictive adverse-event detection: Natural language processing (NLP) and ML applied to heterogeneous data sources will identify safety signals earlier, predict patients at high risk of adverse drug reactions, and automate portions of regulatory signal management [94].

5. Medication adherence, patient engagement and remote monitoring: AI-driven reminders, conversational agents, and pattern-detection from smart packaging or wearables will improve adherence for chronic disease patients [95].

6. Automation, robotics and operational efficiency in pharmacy practice: Robotic dispensing, AI-optimised inventory management, demand forecasting, and automated compounding will reduce dispensing errors and free pharmacists' time for clinical tasks [96].

7. New roles, training and workforce transformation: As routine tasks become automated, pharmacists' roles will shift toward clinical oversight, AI system governance, interpretation of model outputs, and patient counselling [97].

8. Regulatory frameworks, transparency and ethics: Regulators are actively scoping AI/ML frameworks covering lifecycle monitoring, explainability, bias mitigation, and software as a medical device (SaMD). Ethical issues must be embedded into development pipelines [98].

9. Interoperability, data quality and real-world evidence (RWE) pipelines: Investments in standards, curated labeled datasets, and validated RWE pipelines will drive more trustworthy models [99-100].

10. Practical path to adoption: Widespread, safe adoption will depend on hybrid designs where AI augments rather than replaces pharmacists: AI proposes options; pharmacists validate and contextualise decisions [110].

X. RESULT & DISCUSSION

The review demonstrates that Artificial Intelligence (AI) has become a transformative technology in the pharmaceutical and healthcare sectors, significantly improving efficiency, accuracy, and decision-making. Across drug discovery, development, diagnosis, and pharmacy practice, Al provides faster data processing, automation, and predictive analytics that outperform traditional manual approaches. AI-based tools such as IBM Watson, AtomNet, GAN-based drug- design platforms, automated dispensing robots, and deep-learning diagnostic models show strong capability in reducing medication errors, accelerating drug design timelines, enhancing patient counseling, and improving disease detection, especially in radiology, cardiology, and ophthalmology. The findings indicate that AI helps shorten drug-development cycles, supports personalized medicine, optimizes clinical workflows, and improves patient outcomes while reducing human workload. AI also strengthens pharmacy operations through inventory optimization, medication-adherence monitoring, and telehealth-supported patient engagement.

Overall, the results confirm that Al is reshaping the pharmaceutical industry, offering substantial benefits in speed, cost reduction, accuracy, and clinical effectiveness, and is expected to become an essential component of future pharmacy practice and healthcare delivery.

X.CONCLUSION

Artificial intelligence has emerged as a powerful catalyst for progress in the pharmaceutical and healthcare sectors. By enabling machines to analyze complex data, recognize patterns, and automate routine processes, AI is reshaping how drugs are discovered, developed, and delivered to patients. Its integration into areas such as drug design, diagnostics, clinical decision support, and pharmacy automation has led to faster workflows, fewer errors, and more personalized treatment approaches. AI-driven tools from deep-learning diagnostic systems to automated dispensing robots and smart clinical algorithms are helping healthcare professionals make quicker, more accurate decisions while reducing the burden of repetitive tasks. In pharmacy practice, AI supports medication management, inventory optimization, patient monitoring, and telehealth services, allowing pharmacists to prioritize direct patient care and clinical responsibilities.

As pharmaceutical companies increasingly adopt AI in research and development, the industry is moving toward more efficient clinical trials, improved identification of drug targets, and quicker evaluation of therapeutic candidates. Although challenges remain—such as data privacy, model transparency, and regulatory considerations—the progress made so far demonstrates that AI will continue to be a key driver of innovation. Overall, the evidence shows that AI is not just an emerging technology but a transformative force that is redefining the future of pharmacy and healthcare. With ongoing advancements, AI will further enhance patient safety, support evidence-based practice, and accelerate the development of new therapies, contributing to a more efficient and patient-centered healthcare system.

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