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Artificial Intelligence (AI) in Pharmacy

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ABSTRACT: The development of Artificial Intelligence (AI) technology has had a tremendous effect on the field of pharmaceutical care and healthcare. Thus, the article is dedicated to identifying current and future trends
of the application of Artificial Intelligence to pharmaceutical practice, drug development, and patient care. The utilization of machine learning, deep learning, and automation allows for processing massive amounts of data, which contributes to faster drug development, clinical trials, and personalized treatment approaches. Among other technologies, robotic pharmacy systems used to automate the dispensing process, diagnostic models based on AI in radiology, cardiology, and ophthalmology can be emphasized.
In addition, the article outlines changes in the role of pharmacists, who tend to shift towards providing
patient-oriented clinical services, thanks to the application of predictive analytics and AI in
general. On one hand, AI can contribute to solving many challenges in pharmacology and healthcare,
such as medication errors. On the other hand, certain issues should be considered when implementing
this innovative approach, namely, those related to data security and bias in algorithms.

KEYWORDS: Artificial Intelligence, Pharmacy Practice, Drug Discovery, Machine Learning, Healthcare Automation, Personalized Medicine

I. INTRODUCTION

The science of artificial intelligence deals with the development of machinery or computer-based tools that could effectively carry out tasks that would normally call for high-level human thinking skills. This entails collecting data, designing a system for its processing and learning, and producing a logically based conclusion while consistently improving itself using feedback and corrections. All in all, artificial intelligence helps develop machine learning tools which mimic human thinking, analysis, and problem-solving capabilities. This is due to the use of advanced statistical models and computational intelligence, which allows a better evaluation of the data. Hence, artificial
intelligence has become one of the key technologies used in developing efficient analytical tools. Pharmacies, if they are well -equipped, have the possibility of becoming centres of health management rather than just facilities for drug dispensation. In recent times, there has been an explosive growth in the data digitalization by the pharmaceutical sector.
AI technologies are currently extensively used for purposes of collecting, analysing and putting information to work, enabling doctors to handle difficult cases in medicine in a better way. Automation through AI is one efficient tool for managing large amount of information. This technology has been widely used in pharmacy practice over the years, delivering benefits such as time and money saving as well as simplification of numerous pharmaceutical processes. As per McKinsey Global Institute, AI technology in the pharmaceutical industry has the potential to yield revenues of more than $100 billion every year in the US healthcare system .It is expected that AI technology will have huge potential in transforming different areas of pharmacy practice, including drug delivery chain, drug safety, drug management and patients' well -being .
AI chatbots can interact with people in a

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meaningful and conversational way. In the event of any difficult questions, they will be able to easily pass them to a human collaborator who can offer the personal touch. The collaboration of Walgreens with the telehealth provider Medline to offer video consultation services to patients with healthcare professionals is yet another example. In the case of retail pharmacists, AI technologies could help in controlling their stocks through forecasting their needs, stocking shelves adequately, and informing patients about timely support. AI-enabled
data analytics can predict patients' needs in advance and make smart decisions on inventory control. Thus, pharmacists could be relieved from being busy with prescribing tasks only through the integration of AI in pharmacy practice. They could then concentrate on offering support to patients in taking advantage of their drugs and keeping good health cost-effectively.

1. Materials and Methods

This article offers a comprehensive review of the application of Artificial Intelligence (AI) in the field of medicine and pharmacy. An exhaustive search for relevant literature about AI use in the pharmaceutical industry has been performed to highlight its potential applications, benefits, and drawbacks. Various online databases, like Google Scholar, PubMed, ScienceDirect, and official pharmaceutical journals, have been used for this purpose. The literature search was based on the following keywords: "Artificial Intelligence," "Machine Learning," "Drug Discovery," "Pharmacy Automation," "Robotic Pharmacy," and "Personalized Medicine."

Only those articles that had been published during the past ten years were taken into consideration. Information concerning different AI-based approaches, such as IBM Watson and Atom Net, along with the fields of their applicability, have been gathered to assess their revolutionary influence on health care and pharmacy practices.

2. DRUG DISCOVERY VIA ARTIFICIAL INTELLIGENCE

It may take quite some time to conduct trials for a particular chemical substance on sick cells in pharmacological testing. Searching for physiologically active chemicals that are worth investigating takes additional effort. Researchers at Novartis have been able to identify potentially useful untested chemicals by analysing pictures through a machine learning algorithm. If novel and effective drugs are discovered faster through computer simulation than the traditional approach of
manual analysis and testing of chemicals, then the costs involved with examining each individual chemical will become cheaper. The major biopharmaceutical companies are currently working towards the creation of an AI project involving:

• Health results: This could be done via the use of a mobile device. Collection of live data facilitates
the suggestion of a suitable patient resulting in better patient health.

• Drug discovery: This involves drug discoveries in a costly and lengthy process in collaboration between pharmaceutical companies and software companies using the latest technology.

2.1. Medicine and Care

There exists a huge potential in using Artificial Intelligence (AI) in medicine because there is a lack of competent employees in this area. Currently, four types of application have proven to show the greatest promise: The experience of many years of work is required in order to diagnose a disease. Diagnosing a disease is a very long process and consumes lots of time despite the years of training. Because of the lack of skilled personnel, the demand usually exceeds the offer. There has been some considerable progress made in autonomous diagnosing of diseases due to the deep learning algorithms used in the past few years.

2.2. Pharmaceutical Development

The development of novel pharmaceuticals is an extremely costly and time-consuming process. The various analytical methods can easily be cut down with the help of artificial intelligence at various stages in the development of new drugs. This can enable the pharmaceutical companies to save both time and money that they would have otherwise spent for years in research. Artificial Intelligence is already being effectively utilized at all four stages in the development of pharmaceuticals, namely:

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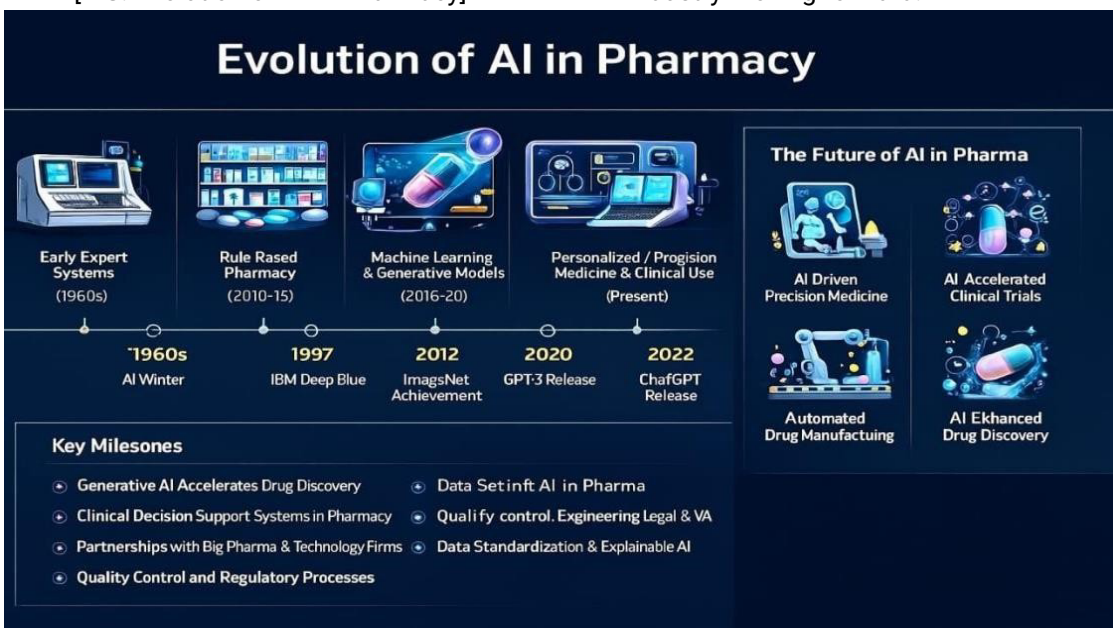
1. Goal identification
2. Patient identification
3. Speed up clinical trial
4. Diagnosis biomarker identification

3. AI'S IMPACT ON THE PHARMACEUTICAL INDUSTRY

The pharmaceutical sector has traditionally been one of the most highly regulated industries globally. This is mostly since the medicines created by pharmaceutical firms have a significant influence on human health. As a result, decision-making in the pharmaceutical industry has been dominated by human knowledge and expertise, which determine which medicines to produce and distribute. Nevertheless, with the emergence of artificial intelligence (AI), pharmaceutical businesses have begun to see the value of employing AI in some of the standard procedures in drug development and manufacturing. To start with, AI can be utilized to evaluate data in search of drug targets and planning clinical studies. On the other hand, AI can help create marketing materials and maintain client relationships.

There are several justifications for why AI is well-suited for carrying out these jobs. For one thing, AI excels at processing vast quantities of data. In the pharmaceutical business, the amount of data to be analysed is enormous since making wise choices needs substantial information. Second, AI excels at performing repetitive activities efficiently and precisely.

[FIG. Evolution of AI in Pharmacy]



4.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. 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.

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 &

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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.

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 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, Atom wise introduced Atom Net, the first deep learning neural network specifically designed for structure-based drug discovery and design. Atom Net 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, Atom Net 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.

Insilco Medicine announced an AI project by the company called Pharm AI. Insilco 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, Insilco Medicine claims to generate novel molecular structures and explore the biological origins of diseases.

5.TOOLS OF AI

5.1. 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 .WFO ranks proposed treatment strategies as "recommended," "for consideration," or "not recommended," providing justification and citations to medical studies and guidelines for each suggestion .

5.2. 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].

5.3. 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.

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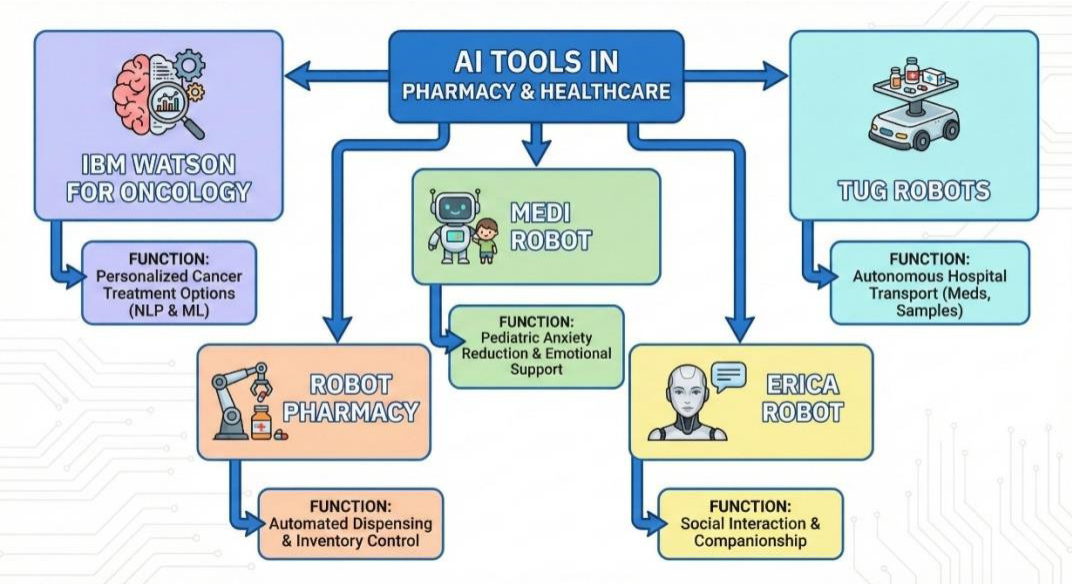
MEDi helps improve cooperation, lowers stress, and creates a more positive experience for young patients during injections, tests, or hospital visits [55-56].

5.4. 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.

5.5. 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.

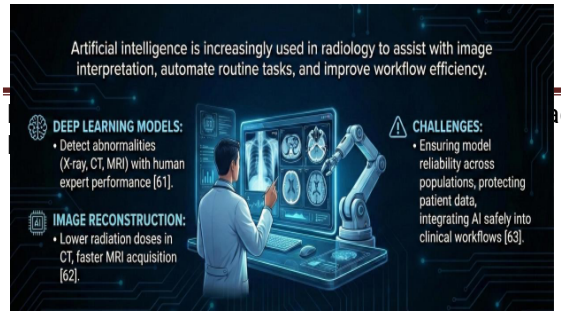


II. [FIG. TOOLS OF AI]

6.ARTIFICIAL INTELLIGENCE IN VARIOUS FIELDS OF HEALTH CARE

6.1.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. AI also supports image reconstruction, enabling lower radiation doses in CT and faster MRI acquisition. 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.



6.2.AI in Cardiology

Artificial intelligence is increasingly used in cardiology to improve diagnosis, risk prediction, and treatment decisions. Machine-learning models can analyze ECGs, echocardiograms, cardiac CT, and MRI to

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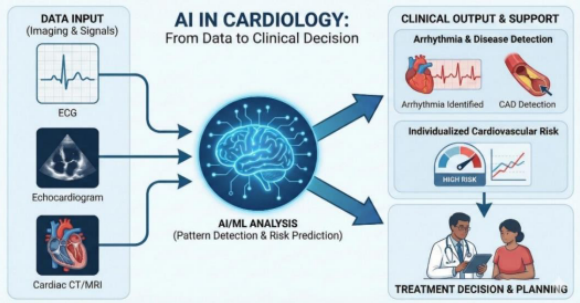
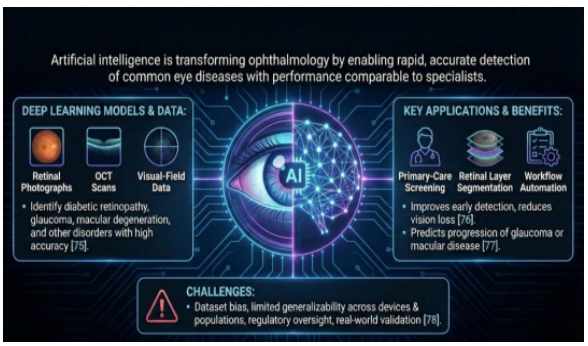
detect subtle patterns not easily recognized by clinicians. Deep-learning systems have shown high accuracy in identifying arrhythmia, predicting heart failure decompensation, and detecting coronary artery disease from imaging. AI-enabled clinical decision support tools can integrate electronic health-record data to estimate individualized cardiovascular risk and guide therapy selection. Although promising, challenges remain related to data quality, algorithm transparency, bias, and clinical validation.



6.3.AI in Ophthalmology

Artificial intelligence is transforming ophthalmology by enabling rapid, accurate detection of common eye diseases. 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. AI systems support screening in primary-care settings, improving early detection and reducing preventable vision loss. They also assist clinicians by segmenting retinal layers, predicting progression of glaucoma or macular disease, and automating workflow tasks. Despite major advances, challenges include dataset bias, limited generalizability across imaging devices and populations, and the need for regulatory oversight and real-world validation.



7.APPLICATIONS OF AI IN PHARMACY

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

• 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 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 considering all the prior data and reports, clinical competence, etc. IBM Watson for Oncology is a cognitive computing decision assistance system that compares patient data to thousands of historical cases and insights gained by working with Memorial

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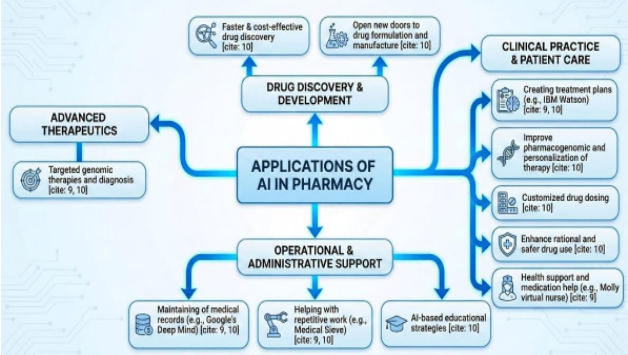
Sloan Kettering Cancer Centre physicians.

• Helping with repetitive work: AI technology also helps with certain repetitive chores, such as analysing radiology, X-ray imaging, ECHO, ECG, and other data for the purpose of identifying and detecting illnesses or problems. Medical Sieve, 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, 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 Ai Cure 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 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 Atomise 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". Data from social awareness algorithms can be gathered and compared for usefulness. Ecosystems can analyse this vast amount of data and provide recommendations regarding the patient's behaviours and way of life.

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

[Fig. Application of Ai in Pharmacy]

8.FUTURE DIRECTIONS

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.

• 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.

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- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- Interoperability, data quality and real-world evidence (RWE) pipelines: Investments in standards, curated labelled datasets, and validated RWE pipelines will drive more trustworthy models.

- 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 decision

II. CONCLUSION

Artificial intelligence (AI) is becoming a major force in pharmacy and healthcare. It helps analyze large amounts of data, identify patterns, and automate routine tasks, making healthcare faster, safer, and more efficient. AI is widely used in drug discovery, disease diagnosis, clinical decision-making, and pharmacy automation. Tools such as smart diagnostic systems, automated dispensing machines, and clinical support software help healthcare professionals make accurate decisions and reduce workload. In pharmacy practice, AI improves medication management, inventory control, patient monitoring, and telehealth services, giving pharmacists more time to focus on patient care. In the pharmaceutical industry, AI is speeding up research by helping identify drug targets, improve clinical trials, and evaluate new medicines faster. Although issues like data privacy and regulations still need attention, AI has already shown great potential. Overall, AI is transforming healthcare into a more efficient, accurate, and patient-centered system.

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