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A REVIEW ON: FUTURE OF ARTIFICAL INTELLIGENCE IN PHARMACY PRACTICE

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Abstract:

From being a tool for resolving data-intensive issues, artificial intelligence (AI) has developed into a revolutionary force in many areas of healthcare, including pharmacy. Its use into pharmaceutical practice has improved efficiency and accuracy by supporting cutting-edge diagnostic technologies, automating difficult processes, and enhancing data management. medication discovery, dosage-form design, polypharmacology, medication repurposing, and hospital pharmacy operations are just a few of the important pharmaceutical areas where AI applications have grown in recent years. This paper offers a thorough analysis of AI-driven innovations that are changing drug research and pharmacy practice. It emphasizes how AI may speed up drug discovery processes, improve medication management, streamline clinical trials, and enable individualized patient care.

The paper addresses crucial issues pertaining to data privacy, algorithmic transparency, and ethical considerations while also discussing tools and approaches that facilitate the application of AI. An exhaustive literature review from PubMed, Semantic Scholar, and diverse databases was part of a rigorous technique that included natural language processing for thematic analysis and AI-enhanced search methods. The results highlight AI's increasing influence on pharmaceutical innovation, its capacity to optimize workflows, and its potential to enhance patient outcomes in the future.

Keywords : *Artificial intelligence in pharmacy; machine learning in drug discovery; personalized patient care; inventory management in pharmacies; medication adherence monitoring; patient-centered care; pharmacists and AI integration*

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1. INTRODUCTION:

In several industries, including healthcare, artificial intelligence (AI) has become a cutting- edge technology that has the potential to transform drug research and improve pharmacy procedures. The ongoing growth of AI, driven by developments in data science and machine learning, has made it easier to create creative answers to challenging problems in the pharmaceutical industry. The development of algorithms that can learn, adapt, automate procedures, and carry out complex data analysis is what drives the adoption of AI and opens the door to improved operational efficiency and decision-making. The pharmaceutical sector, which is propelled by significant financial investments and a growing market, is fast changing as a result of integrating AI into drug research.By 2023,

In 2023, the global AI in drug discovery market was valued approximately $1.5 billion, with projections indicating a compound annual growth rate (CAGR) of 29.7%, potentially reaching $11.8 billion by 2030 . [1]

Since the 1980s, computers have been used in pharmacies for a variety of purposes, including data collection, retail pharmacy management, clinical research, drug storage, pharmacy education, clinical pharmacy, and many more. With the advent of artificial intelligence, it is impossible to predict how much the pharmacy industry will change over time. Many expert systems have been developed in the medical field to help doctors diagnose patients. There have been descriptions of various pharmacological therapy-focused programs recently. They direct the choice of drug formulary, monitoring of drug therapy, and interactions. AI has the potential to affect many facets of pharmacy, and pharmacists should think about these possibilities as they may eventually become a reality in pharmacy practice. [2]

1.1. Artificial intelligence in healthcare

Over the past 50 years, AI in healthcare has undergone tremendous change, resulting in notable breakthroughs across numerous medical specialties. Instead of depending only on algorithms, personalized medicine is now possible because to the development of machine learning (ML) and deep learning (DL). Clinical decision-making, disease diagnosis, and clinical, diagnostic, rehabilitative, surgical, and prognostic procedures have all been greatly impacted by AI. enhanced clinical operation efficiency, disease and treatment monitoring, faster provider workflow, enhanced diagnostic accuracy, accurate operations, and ultimately better patient outcomes are all made possible by this innovation in AI technology. [3]

1.2. Pharmacy practice

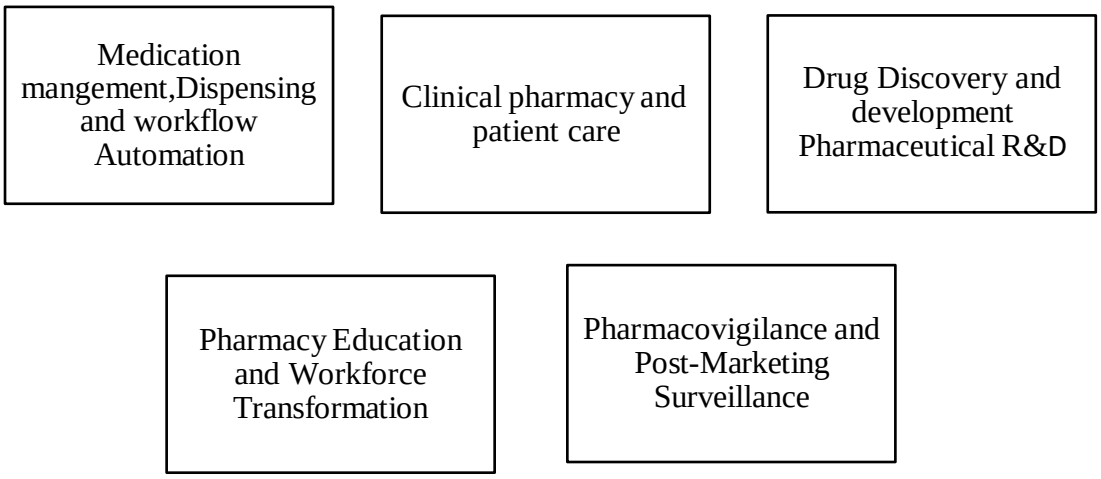
Through a variety of activities, including medication reconciliation, medication review, medication therapy management (MTM), drug information provision, patient education, adverse drug reaction (ADR) monitoring, and interprofessional collaborations, pharmacy practice is an essential component of the healthcare system that guarantees safe and effective medication management and optimal patient care. [4]The amount of prescriptions, complicated medication regimens, and administrative duties have all significantly expanded due to the healthcare industry's rapid improvements. Because of this, there is a growing need for cutting-edge technical solutions that may help healthcare workers with their everyday tasks and enhance the provision of healthcare services. [5] Pharmacists can make precise and evidence-based healthcare judgments with the use of tools and systems made possible by the integration of AI technologies.

By using AI algorithms and ML, pharmacists can quickly analyze large amounts of patient data, including medical records, lab results and medication profiles. This allows them to identify potential drug-drug interactions, assess the safety and efficacy of medicines, and make informed recommendations tailored to individual patients [6]The use of AI in pharmacy practice has demonstrated promising results in a number of domains. To fully utilize AI technology, however, current research gaps must be filled. The most crucial component is fully integrating AI services into current pharmaceutical systems and comprehending how they affect both economic and health outcomes. The numerous AI applications in the field of pharmacy practice will be examined in this study, along with the research gaps and
difficulties as well as potential future research avenues.. [7]

1.3 The objectives of the study are:

- Assess how well the new AI-powered pharmacy system performs in contrast to the previous manual pharmacy system.
- To evaluate how the AI-powered pharmacy system affects cost reductions, patient outcomes, efficiency, and regulatory compliance.
- To assess the viability and usefulness of deploying the AI-powered pharmacy system in various healthcare environments.
- To determine any possible disadvantages or difficulties related to putting the AI-powerpharmaceutical system into practice• To offer suggestions for next studies and advancements in AI-powered pharmacy system. [8]

2. Current State of AI in Pharmacy Practice



2.1 Medication Management, Dispensing and Workflow Automation

Automation of Workflow,Dispensing, and Medication Management AI is now being developed or used in inventory management, medicine evaluation, and dispensing. For instance, a recent scoping analysis (2018–2023) found that the majority of AI implementations in pharmacy practice have concentrated on patient-facing mobile applications, screening services, and the identification of prescriptions requiring pharmacist intervention[9]

Additionally, a 2024 narrative review shown that in high-volume dispensing settings, AI-driven systems—such as automated dispensing devices, computer-vision verification tools, and ML-based systems—are increasing accuracy, decreasing human error, and boosting patient safety [10] Another recent study outlined the existing applications of AI in pharmaceutical sector contexts, including community and hospital pharmacies, emphasizing enhancements in workflow efficiency, inventory management, and medication-order checking. [11]

2.1 Clinical Pharmacy & Patient Care Applications

Intelligent decision-support systems can help with dose optimization, drug-drug interaction assessments, adherence monitoring, and therapy modifications based on patient data. AI is being used more and more to support clinical pharmacy operations. [12]
New AI-powered patient-facing services are also being investigated for pharmaceutical counseling, adherence assistance, and individualized therapy guidance (e.g., via mobile applications, virtual assistants). [13]

2.2 Drug Discovery and Development, Pharmaceutical R&D

AI has significantly advanced medication discovery, formulation development, and pharmaceutical R&D in addition to dispensing and patient care. Target discovery, drug creation, structure–activity relationship predictions, and pharmacokinetic/pharmacodynamic modeling are currently all done using ML and DL algorithms. [14] According to a recent review from 2025, AI shortens the time it takes to find new drugs, lowers costs, and increases the accuracy of compound optimization and drug-target interaction predictions.[15]

2.3 Pharmacy Education and Workforce Transformation

By improving experiential learning, AI-based simulation technologies and virtual patient systems are revolutionizing pharmacy education. AI literacy will be included into future courses to prepare students for data-driven clinical practice. [16]

2.4 Pharmacovigilance and Post-Marketing Surveillance

AI-enhanced pharmacovigilance systems analyze wearable data, social media posts, and electronic health records (EHRs) to identify ADR patterns earlier than traditional methods.This real-time monitoring improves patient safety and allows for quicker risk minimization. [17]

3. Emerging Trends & Future Directions:

The following patterns and future directions are projected based on current literature:

- Deep Integration of AI into Routine Pharmacy Practice: AI-powered CDSS, automated dispensing, inventory management, and pharmacovigilance may become commonplace in community and hospital pharmacies, improving accuracy and allowing pharmacists to concentrate on clinical and patient-centred responsibilities. [18]
- Transition from Operational to Clinical and

Cognitive duties for Pharmacists: As AI takes care of routine activities like inventory, dispensing, and checks, pharmacists' duties may
change to include patient counselling, medication treatment management, therapeutic decision making, and interprofessional coordination.

- Precision medicine and pharmacogenomics: combining AI with patient-specific data (genomics, lab results, comorbidities) may enable completely customized treatment, maximizing effectiveness and reducing side effects.
- Tele pharmacy, Remote Care & Patient Engagement: AI-enabled telehealth platforms,

virtual counselling, remote monitoring, adherence support, and patient education tools will increase access to pharmaceutical care, particularly in underserved or remote places.
Tele pharmacy, Remote Care & Patient Engagement: remote monitoring, virtual counselling, telehealth solutions with AI capabilities, Integration Throughout the Drug Lifecycle: From Development to Dispensing: AI will play a part in post-market pharmacovigilance, drug development, manufacturing, and dispensing. Closing gaps in the pharmaceutical supply chain to facilitate safer, quicker, and more effective drug delivery. [19] .

4. Challenges, Risks & Barriers to Implementation

Despite its promise, integrating AI into pharmacy practice comes with significant challenges:

- Data security, ethics, and privacy: AI systems need access to a lot of private medical data. Major problems include obtaining informed consent, maintaining confidentiality, protecting data, and adhering to privacy laws.
- Algorithmic bias and transparency: AI recommendations may be biased or lead to unfair treatment if training data are not representative. Regulatory acceptance and trust might be hampered by a lack of explainability.
- Interoperability, data standards, and infrastructure constraints: Systems like EHRs, pharmacy management software, laboratory data, and dispensing equipment must interoperate and maintain data quality in order for AI to work successfully. This is particularly difficult in settings with limited resources.
- Workforce readiness and training requirements: If pharmacists and associated personnel are not trained to use AI tools, understand AI outputs, and maintain clinical oversight, there is a danger of over-reliance on automation.

Regulatory, legal, and ethical oversight gaps: Strong frameworks are required to control the use of AI in healthcare, including who is responsible for mistakes made by AI, how to verify and audit AI-based judgments, and guaranteeing patient safety.

- Concerns about equity and access: Implementation may favour hospitals and pharmacies with more resources, creating a gap in AI-enabled treatment; rural or underfunded pharmacies may fall behind.

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5. AI's possible uses in pharmaceutical systems

By offering patients and healthcare professionals individualized, real-time help, AI-powered conversational agents have the potential to completely transform the pharmaceutical system.

It can comprehend and interpret patient demands and deliver precise and prompt responses thanks to its machine learning algorithms and natural language processing (NLP) capabilities. AI has several uses in pharmacy, from data analytics to prescription management.

This technology can improve patient outcomes, reduce healthcare costs, and enhance the efficiency of healthcare delivery. This article will discuss the potential applications of AI in pharmacy and how it can transform the future of healthcare, Also after identifying the areas of research the following probable applications can be seen in pharmacy .[20]

Artificial intelligence (AI) is altering the pharmacy sector and quickly changing its future. AI has immense potential in pharmacy, from patient care to drug discovery. Drug discovery, clinical decision-making, prescription management, and patient monitoring are just a few of the parts of the pharmacy system that AI can assist to automate and streamline. Large volumes of data may be swiftly analysed by AI-powered systems, yielding insights that can assist pharmacists in making wise patient care decisions.[21]

6. Explainable Artificial Intelligence (XAI) in Pharmacy Practice

The goal of explainable AI is to make AI decision-making clear and intelligible to
pharmacists. XAI can assist pharmacists in understanding why an AI system suggests a specific medication, modifies a dose, or warns of a drug-drug interaction. This improves

trust, accountability, and regulatory acceptance of AI tools in clinical decision-making [22]

7. AI in Pharmacoeconomics and Health Technology Assessment (HTA)

The use of AI models in healthcare cost analysis, therapy cost-effectiveness, budget impact analysis, and reimbursement choices is growing. AI in pharmacy can help hospital
pharmacists and legislators choose economical and efficient treatment plans.[23]

8. AI in Regulatory Affairs and Compliance Monitoring

AI solutions support adverse event reporting, automated document analysis, regulatory
submissions, and adherence to international regulatory standards (FDA, EMA). AI expedites approval processes and lowers documentation errors in pharmacies..[24]

DISCUSSION:

Analysing the connections between treatment or preventative strategies and patient outcomes is the main goal of health-related AI applications. AI programs have been created and used in a variety of fields, including patient monitoring and care, drug discovery, diagnosis procedures, treatment protocol development, and personalized medicine. Here are some ways pharmacists can use the ongoing technological expansion to influence value-based outcomes as patient care quality continues to gain significance. Pharmacies can become health management centres rather than just places to fill prescriptions because they are the most easily accessible and reasonably priced healthcare stakeholder.

A wider range of services (such as vaccines, screenings, MTM, and disease status management) as well as more individualized healthcare solutions can be made possible by technology. Wearable technology and health trackers will be able to collect data in real time, allowing pharmacies to evaluate the quality of improvement and follow up with at-risk patients regarding their illnesses.

We currently use an early version of AI in pharmacy. It is referred to as our pharmacy management system, which houses drug data, patient utilization, and the possibility of detecting drug-related issues through clinical decision support screening. A technology-based information expert system that uses patient data gathered from the pharmacy system to promptly identify drug-related issues is the next generation of pharmacy technology. their external data systems. Consistent with workflow robotics, this would leave less of the work on the pharmacist to shoulder the responsibility of identifying serious drug-related problems.

CONCLUSION:

From regular dispensing and inventory management to individualized therapy, clinical decision support, tele pharmacy, and drug development integration, AI has the potential to significantly change pharmacy practice. Emerging trends indicate a transition toward a more clinical, patient-centred, data-driven model of pharmacy, even though present implementations are still somewhat small and frequently focussed on operational efficiency.

However, in order to fully realize this promise, a number of obstacles must be carefully considered, including data privacy, algorithmic bias, human oversight and training, regulatory frameworks, and fair access. AI may change the role of the pharmacist, improve patient outcomes, and increase the safety, effectiveness, and reach of pharmaceutical care with careful integration—through interdisciplinary collaboration, pilot deployment, capacity training, and strong governance.

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