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Review Article

Artificial Intelligence and the Changing Role of Pharmacists: From Medication Dispensers to AI-Assisted Clinical Decision-Makers

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ABSTRACT

Artificial intelligence (AI) is revolutionizing pharmacy practice by facilitating the analysis of large amounts of clinical and pharmaceutical data, aiding medication management, strengthening medication safety and encouraging patient-centred care. The traditional role of the pharmacist in dispensing and supply is being transformed into that of clinical decision making, medication optimization, therapeutic monitoring and individualized care. This review discusses the major applications of AI in pharmacy and the changing role of pharmacists in AI-assisted clinical practice. Machine learning, deep learning, natural language processing, generative AI and AI-enabled clinical decision-support systems have shown promise in prescription screening, detection of drug–drug interactions and prediction of adverse drug events, decrease in medication errors, dose optimization and personalized pharmacotherapy. These tools can also help streamline workflow and save time for pharmacists to focus on clinical interventions and patient counseling by taking on repetitive data-heavy tasks. However, pharmacists remain indispensable for clinical interpretation, ethical reasoning, patient-specific assessment, and final therapeutic decisions, so the successful implementation relies on effective human–AI collaboration. The uptake of AI also brings concerns around data privacy, algorithmic bias, professional responsibility, legal uncertainty, transparency and patient safety and pharmacy education will need to incorporate digital skills and AI literacy into pharmacist training. AI with appropriate oversight by humans, ethical safeguards and robust regulation can enhance pharmacy practice and facilitate the transition of pharmacists from medication dispensers to AI-assisted clinical decision-makers.

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INTRODUCTION:

AI is now part of many areas of healthcare practice and this encompasses pharmacy practice. AI-based tools have been used in drug–drug interaction screening, personalized medicine and the automation of dispensing, and are increasingly being used to manage medicines, support clinical decisions and improve patient outcomes.

Pharmacy itself has changed a lot. Whereas previously the practice was largely defined by the supply of medicines, it has evolved to be a more patient centered and clinically driven practice, with pharmacists taking an active role in medication management and therapeutic decisions. This shift requires pharmacists to interpret complex patient information, including medication histories, lab results and potential drug-related problems, and AI offers new ways to support this work. Machine learning and clinical decision-support systems can analyze large volumes of healthcare data, flag drug–drug interactions, predict adverse drug events, identify medication-related risks and assist to tailor therapy to the individual patient.

In reality, though, current applications are fairly narrow. They focus on medication adherence, workflow optimisation, prescription screening and detection of inappropriate medication orders Increasing AI capability in clinical prioritisation and data analysis could enhance the involvement of pharmacists in the whole patient-care process.

The complexity of current pharmacotherapy, medication-related problems, and the need to improve productivity are increasingly driving the need for AI-assisted practice, freeing pharmacy professionals to focus on clinical decisions and patient care. It should be considered as an adjunct to the chemist's expertise and clinical judgement, not a replacement. The review highlights the key artificial intelligence (AI) tools applied in pharmacy, summarises their applications, considers how the role of the pharmacist is evolving and discusses the ethical, regulatory and educational issues associated with these developments [1].

1.1 Emergence of AI in Healthcare

Financial pressures on health systems continue throughout the world. Healthcare costs have increased faster than GDP in many countries, threatening the long-term sustainability of care. The pandemic and the war in Ukraine made these pressures more visible. Tight budgets, ageing populations, a growing burden of chronic disease and rising demand for services have left many systems struggling to maintain access and availability. The pandemic put severe strain on health systems in countries such as India, Brazil and Indonesia. In this context, AI is seen more and more as a method for better use of scarce resources [2].

1.2 The Need for AI-Assisted Pharmacy Practice

Computers first appeared in the pharmacy setting in the 1980s and it is believed that AI-based approaches followed shortly thereafter. The early machine learning applications were used to support several functions in pharmacy including data collection, dispensing histories, retail pharmacy management, clinical research, drug storage, pharmacy education, and clinical pharmacy.

They were also used in pharmaceutical industry, e.g. to evaluate compound properties, design new compounds de novo, study drug-receptor interactions and predict drug reactions. More recently, the focus has shifted to generative and conversational technologies such as chatbots for medication management and recognising potential drug-related problems for clinical review [3].

2. SCOPE AND APPROACH OF THIS REVIEW:

The review was performed as a narrative literature review with a focus on the applications of artificial intelligence (AI) in pharmacy practice and the resultant changes in the professional roles of pharmacists. The review focused on developments in machine learning, deep learning, natural language processing, generative AI, large language models and AI-enabled clinical decision-support systems regarding prescription screening, medication safety, drug–drug interaction detection, adverse drug-event prediction, medication management, dispensing, dose optimization, personalized pharmacotherapy, patient care and clinical decision-making. When the goal is not to answer a focused systematic-review question, narrative reviews can provide a broad synthesis of evidence across a developing field.

A literature search was conducted in major biomedical and multidisciplinary electronic databases including PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect and Google Scholar.Reporting the information sources and search approach enhances transparency, and the reader can understand how the relevant literature was identified.

Eligible publications were peer-reviewed original research articles, systematic reviews, scoping reviews, narrative reviews, and other relevant scholarly literature on AI applications in pharmacy practice, evolving roles of pharmacists, medication safety, clinical decision support, human-AI collaboration, ethical and regulatory considerations, and pharmacy education. Articles not related to pharmacy or healthcare applications, studies only focusing on the technical development of AI without relevance to pharmacy practice, duplicate records and publications without sufficient relevant information were excluded.

The retrieved literature was screened first by title and abstract and then the full text articles that were potentially relevant were assessed against the pre-defined eligibility criteria. Thematic synthesis of relevant evidence was then undertaken based on artificial intelligence (AI) technologies, applications in pharmacy practice, evolving pharmacist responsibilities, human–AI collaboration, ethical and regulatory considerations, and pharmacy education. Transparent reporting of literature identification and study-selection procedures is recommended to enhance the reproducibility and credibility of evidence synthesis.

3. AI TECHNOLOGIES IN PHARMACY:

Artificial intelligence is the term applied to computational systems that carry out tasks typically linked to human thought processes, including learning, reasoning, processing language, recognising patterns and solving problems. In pharmacy, AI has emerged as a practical approach to address the growing size and complexity of data related to medications. The literature [2–4] describes its growing incorporation into clinical pharmacy services, including medication management, prescription review, medication safety, detection of adverse drug events and therapeutic decision-making. The technologies most relevant to pharmacy are machine learning, deep learning, natural language processing, generative AI and AI-enabled clinical decision-support systems (Table 1). They analyse massive amounts of electronic health records and medication data, which helps chemists identify risks and make better decisions.[4]

Table 1: Main AI Technologies in Pharmacy Practice and Their Typical Applications.

AI technology	Typical applications in pharmacy	Main considerations
Machine learning and deep learning	Prediction of adverse drug events; identification of potentially inappropriate medications; detection of medication errors; drug-related risk assessment; prescription analysis	Performance depends on the quality and representativeness of training data (see Section 5.2)
Natural language processing	Extraction of clinically relevant information from prescriptions, clinical notes, electronic health records and adverse drug reaction reports; identification of interactions and side effects	Draws on sensitive unstructured records, so privacy safeguards are needed (see Section 5.1)
Generative AI and large language models	Drug information retrieval; medication therapy management; drug–drug interaction detection; draft patient-management recommendations	Accuracy and reliability vary in complex cases; outputs need verification by trained professionals
AI-enabled clinical decision-support systems	Prescription verification; detection of medication errors and interactions; dose optimisation; identification of potentially inappropriate medications	Intended to support, not replace, pharmacists' judgement; requires transparency and human oversight

3.1 Machine Learning and Deep Learning

Machine learning (ML) is one of the most prevalent forms of AI in clinical pharmacy, ML algorithms mine large datasets and detect patterns missed by conventional methods. Its reported uses include the prediction of adverse drug events, the identification of potentially inappropriate medications, the detection of medication errors, and the assessment of drug-related risk. Deep learning , a more advanced ML branch , uses

multilayered neural networks to analyse complex data and generate predictions with little need for manual feature extraction .

The most prominent among the reviewed studies are ML and deep learning in analysing prescriptions, medication safety, predicting adverse drug effects, and detecting drug interactions. These tools could make data-heavy work easier for chemists and improve the accuracy and efficiency of clinical services.

3.2 Natural Language Processing

Natural language processing (NLP) is a computer science discipline, with the aim of the interaction between computers and human languages. A pharmacy can extract clinically relevant information from unstructured data sources like prescriptions, clinical notes, electronic health records, and adverse drug reaction reports. This can assist chemists in detecting drug related problems, interactions and side effects more efficiently. When combined with other machine-learning techniques, NLP has the potential to convert large amounts of unstructured data into actionable clinical knowledge which can be used to support medication safety and pharmacist-led services.

3.3 Generative AI

Generative AI, especially large language models such as ChatGPT, are attracting considerable interest in pharmacy practice. These systems can produce human-like responses and may be helpful in retrieving drug information, medication therapy management, identifying drug–drug interactions and formulating initial patient-management recommendations. But the evidence reviewed shows variability in accuracy and reliability in complex clinical situations. Generative artificial intelligence can help chemists process and synthesise information quickly, but the output should always be checked by trained professionals. Human supervision is still needed for patient safety, contextual appropriateness and evidence-based decision making.

3.4 AI-Enabled Clinical Decision-Support Systems

AI-enabled clinical decision-support systems (CDSS) integrate patient-specific data, clinical knowledge and computational algorithms to assist clinicians in making informed treatment decisions. In clinical pharmacy they can help with prescription verification, detection of medication errors and drug–drug interactions, dose optimisation and identification of potentially inappropriate medications. Two recent reviews show that such tools are increasingly used in high-volume, high-risk medication-management tasks, where they hold the potential to improve medication safety We're not trying to replace chemists' expertise, we're trying to enhance it. AI-enabled CDSS can perform routine data analysis and flag clinically important risks, allowing chemists to have more time for counselling, medication optimisation and complex clinical decisions.[5]

4. APPLICATIONS OF AI IN PHARMACY PRACTICE:

4.1 Prescription Screening, Interaction Detection and Adverse Event Prediction

AI-based systems can assist in several steps of the medication-use process. They can flag potential drug interactions, medication errors, adverse drug events and inappropriate therapy by analysing electronic health records, laboratory results, medication histories and patient-specific characteristics. The most frequently reported use cases include prescription screening, detection of drug–drug interactions and prediction of adverse drug events. Predictive analytics and clinical decision-support systems can also provide chemists with guidance to optimise drug selection and dosing and support personalised pharmacotherapy.

4.2 Dispensing and Error Reduction

Errors in drug dispensing continue to be a constant threat to patient safety and quality of care. The causes are often look-alike or sound-alike drug names, similar packaging and complex processes. Double-checking, barcode scanning and chemist verification are still essential safeguards, but they are prone to variable procedures, heavy workloads and human fatigue. AI, and especially ML and NLP, can process large datasets and identify discrepancies in near real time, perhaps faster and with more consistency than manual checks alone. But its value will depend on how well it is integrated into the larger healthcare system. AI-enabled approaches to dispensing error prevention were reviewed by Ouda et al., who proposed a systems-based roadmap for their safe and effective use.[7]

4.3 Ai-Assisted Medication Management

Clinical pharmacy services are an important component of safe and effective patient-centred care. Community and hospital chemists carry out or support pharmacovigilance, therapeutic monitoring, prescribing review, medication optimisation and clinical decision support. In this landscape AI has become an enabling technology that utilises computational methods that replicate some aspects of human cognition such as learning, reasoning, pattern recognition and decision-making. AI could improve the precision, efficiency and personalisation of medication management through predictive analytics, automated risk identification, adaptive learning systems and data-driven therapeutic recommendations. It can also help with inventory management and dispensing, so pharmacists have more time for complex clinical interventions and direct patient care. This could lead to a shift from reacting to medication problems after they happen to a more proactive, data-driven model of pharmaceutical care.[8]

5. THE CHANGING ROLE OF PHARMACISTS:

5.1 From Medication Dispenser to Clinical Decision-Maker

Traditionally, pharmacists managed the supply of drugs, prepared and dispensed medications. That picture has been changing for a while. Pharmacists are now widely accepted members of multidisciplinary healthcare teams and are responsible for clinical assessment, optimisation of medications, monitoring, patient education and involvement in therapeutic decisions. AI and the increasing automation of dispensing are speeding up this shift. The automation of routine operational tasks has enabled chemists to spend more time evaluating complex medication-related problems and participating in therapeutic decision-making.

Clinical decision making in pharmacy is a systematic process of integrating patient specific information, pharmacological knowledge, clinical evidence, treatment guidelines and patient preferences, to identify medication related problems and select a safe, effective and individualised therapy. Clinical reasoning is a core competence in this process [8]. Pharmacists' contributions include medication reconciliation and review, dose optimisation, monitoring of adverse drug reactions, assessment of interactions, antimicrobial stewardship, adherence support and collaborative management of chronic disease. Systematic review evidence indicates that pharmacist-led interventions can improve medication safety, disease control, adherence and some clinical outcomes.

While the recommendations are generated by AI, they still need to be interpreted and validated by an expert so the clinical expertise of chemists remains vital to guarantee the treatment choices are suitable for the individual patient. Pharmacists are increasingly expected to combine that expertise with digital competence, so they can interpret AI output and apply it appropriately in patient care.[9]

5.2 Human–AI Collaboration

The future of pharmacy is probably not about technology replacing professionals but about chemists and AI working together. Artificial intelligence systems can evaluate large amounts of clinical data, recognise patterns, and make recommendations quickly. Pharmacists apply clinical judgement, professional experience, ethical reasoning and understanding of the circumstances of each patient. They therefore have to critically appraise AI-generated output and retain responsibility for the final clinical decision. The combination of AI's computational efficiency and chemists' contextual knowledge and patient-centred approach has the potential to improve medication safety and therapeutic outcomes. Implementation will need to include proper chemist training, transparent and trustworthy systems, strong data governance and continuous oversight by humans to ensure AI remains a tool to support professional practice, not replace clinical judgement.[10]

6. CHALLENGES AND ETHICAL ISSUES:

6.1 Data Privacy and Security

AI requires huge amounts of sensitive health data, raising privacy concerns. The problem is illustrated by the data collected routinely by e-pharmacies. Prescription records, medical history, demographic details and payment credentials add up to a highly sensitive profile that most customers wouldn't want shared. Perceived

risk of misuse, through data breaches, third-party sharing or commercial exploitation of health records, has long been recognised as a significant deterrent to both initial and repeat use of such platforms. The issue is not so much whether consumers trust e-pharmacies but how they balance the benefits of these services against the risks to privacy.

Two related concepts are useful to explain this trade-off. Privacy concern is a subjective unease of user about the collection, handling and sharing of personal information . It determines disclosure decisions and perceived risk . Privacy calculation, however, is the ongoing process in which consumers weigh those concerns against the benefits of interacting with a service. This balance is mediated by trust: people who trust a platform are more willing to share information even with reservations and are more likely to read ambiguous signals more generously.[11]

6.2 Algorithmic Bias

In healthcare AI, bias is defined as any systematic and unfair difference in predictions across patient populations that may result in unequal delivery of care. Such differences are the source or exacerbation of disparities in who benefits from, or is harmed by, a given tool, and hence undermine fair and equitable healthcare. The phrase “bias in, bias out”, an adaptation of “garbage in, garbage out”, is often used to describe the failures of models in real-world use: the biases present in the training data tend to re-emerge as poorer performance in practice. Bias may, however, be present at any stage of the algorithm’s life cycle, including conceptualization, data collection, development, validation, clinical implementation and ongoing monitoring. As AI is more and more used to make decisions across a range of fields including public health, there are concerns that it could entrench and even worsen existing biases.[12,13]

6.3 Professional Responsibility

AI is becoming part of daily life and of pharmacy practice. Some believe it is a big step toward better, more efficient care. Others see it as a threat – that it will increase inequality, deskill the workforce and move beyond human understanding and control. The tension between human-in-the-loop and human-out-of-the-loop systems raises specific questions for patient safety, and clear guidance on the ethical use of AI will be crucial to protect patients and the profession.

Pharmacy regulators and the professional bodies are still exploring how standard artificial intelligence can be used safely and responsibly. The benefits to date are measurable. AI scribes save clinicians’ documentation time, large language models have helped patients quit smoking, and other systems have saved lives by alerting clinical staff to patients at risk of deterioration who may need intensive care. These gains are not without patient risks as reported in the literature.[14,15]

6.4 Regulatory Issues

In pharmacy, AI is revolutionising the field with applications in drug development, clinical trials, pharmacovigilance, personalised medicine and supply chain optimisation. It could reduce costs, foster innovation and improve outcomes by offering faster, data-driven insight. However, the regulatory landscape for AI in pharmacy is fragmented and uneven across jurisdictions. Challenges cited include data governance, pace of change in technology, lack of standardisation and limited regulatory oversight. Policy proposals call for flexible, internationally harmonised frameworks balancing innovation with patient safety, transparency and equitable access. If these issues can be addressed by regulators, AI is more likely to be more efficient, ethical and patient-centred. Policy proposals advocate flexible, internationally harmonised frameworks that balance innovation and patient safety, transparency and equitable access. If regulators can tackle these issues, AI is more likely to provide a more efficient, ethical and patient-centred system of pharmaceutical care.[16]

7. IMPACT ON PHARMACY EDUCATION:

As the pharmacist’s role has evolved to be more personalised and patient-centred, with greater management of therapy and disease, pharmacy education and training has had to keep pace. Digital health technologies including telemonitoring, tele-pharmacy and tele-therapeutics now allow students and faculty to mirror current practice developments.[17]

7.1 AI Literacy and Curricular Change

AI is already integrated into many tools that graduates will see in practice, such as clinical decision-support

systems, automated dispensing systems, platforms that predict drug interactions and medication management apps, all designed to improve the efficiency and accuracy of patient care. The selection of formulary drugs, the monitoring of therapy and the checking of drug interactions are also supported by programs. With these technologies being implemented in clinical and industrial workflows, pharmacy curricula need to be updated so that graduates can use AI critically, understand its limits and use it safely. For example, the knowledge, use and perceptions of students of B.Pharm in India have been surveyed.[18]

7.2 AI as a Teaching and Learning Tool

AI is also changing the way students study and engage with the subject. It can help people to understand difficult concepts better, make learning personal and adapt to the needs of each individual. For example, AI-driven simulations and virtual patients allow trainees to practise their clinical decision-making skills in a safe environment. Automation of administrative work could also allow educators to spend more time teaching.[19]

CONCLUSION:

Artificial intelligence (AI) is likely to be a major technology in pharmacy practice and has the potential to shift pharmacists' work from dispensing and administration to patient-centered clinical decision making. The literature reviewed here shows that machine learning, deep learning, natural language processing, generative AI and AI-enabled clinical decision-support systems can support prescription screening, error reduction, interaction detection, adverse event prediction, dose optimisation and personalised pharmacotherapy. They can also relieve chemists of repetitive data-heavy chores, freeing time for monitoring, counselling and other clinical interventions.

AI should be considered an addition to, not a replacement for, the expertise of chemists. Pharmacists have clinical judgement, contextual awareness, ethical thinking and professional accountability, while artificial intelligence systems can process huge volumes of data and make predictions. Cooperation between humans and AI is necessary to guarantee that recommendations are understood, verified and applied correctly.

Quite a few hurdles to overcome there still. Solid governance, data protection, transparent and dependable technologies, and clear regulations must address data privacy, algorithmic bias, professional responsibility, openness, patient safety, and regulatory uncertainty in an effort to preserve public trust. Pharmacy education must keep pace with practice through the development of AI literacy, digital health competency, critical evaluation of AI output, and a clear knowledge of oversight by humans. Armed with these components, chemists could become more active players as AI-assisted clinical decision-makers, while AI is able to help deliver safer, more effective and more personalized pharmaceutical care.

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