



THE UTILIZATION OF ARTIFICIAL INTELLIGENCE IN IMPROVING MEDICATION SAFETY: A SYSTEMATIC REVIEW OF CLINICAL PHARMACY SERVICES

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Abstract

This study aims to analyze the use of *artificial intelligence* (AI) to improve treatment safety in clinical pharmaceutical services. The method used is a *systematic literature review* conducted in accordance with the PRISMA 2020 guidelines. Article searches were conducted in the Scopus, PubMed, Web of Science, and ScienceDirect databases for publications from 2020–2026 using the keywords *artificial intelligence*, *machine learning*, *medication safety*, *medication error*, *adverse drug event*, and *clinical pharmacy*. Articles were selected based on inclusion and exclusion criteria, then analyzed using narrative synthesis and thematic analysis. The results of the study show that AI has been used in prescription review, medication error prediction, drug interaction detection, side effect identification, clinical alert optimization, drug reconciliation, and prioritization of high-risk patients. *Machine learning*, *deep learning*, *natural language processing*, and *clinical decision support systems* can increase the speed of data analysis, the accuracy of risk identification, and the efficiency of pharmacists' work. However, most models still use retrospective data from a single institution, have not undergone external validation, and have limitations in algorithmic transparency, data quality, outcome generalization, patient privacy, and potential bias. These findings confirm that AI should be used as a decision-support tool with a human-in-the-loop approach, rather than as a substitute for pharmacists' professional judgment. Secure implementation requires local validation, periodic audits, integration with electronic medical records, improvement of pharmacists' digital competencies, and clear regulations. Further research needs to test the effectiveness of AI through multicenter prospective studies with measurable clinical, economic, and patient safety outcomes. Overall, AI has the potential to shape clinical pharmacy services that are more predictive, personalized, responsive, and oriented towards the prevention of adverse drug events on an ongoing basis at various levels of healthcare



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INTRODUCTION

Digital transformation has driven fundamental changes in healthcare systems, including clinical pharmacy services. One of the rapidly growing technologies is *artificial intelligence* (AI), which is a technology that allows computer systems to study data, recognize patterns, make predictions, and support clinical decision-making. In pharmaceutical practice, AI is beginning to be leveraged to analyze electronic medical records, identify drug interactions, predict side effects, optimize doses, support therapy selection, and improve patient adherence. These developments show that AI has the potential to transform pharmaceutical services from a reactive approach to a more predictive, personalized, and treatment-risk prevention-oriented service (Alowais et al., 2023; Chalasani et al., 2023).

Treatment safety is still an important issue in the global health system. Errors can occur at the stage of prescription, transcription, preparation, delivery, administration, and monitoring of drug

therapy. The complexity of patient conditions, polypharmacy, limited clinical information, workload of health workers, and weak communication between professions further increase the likelihood of *medication errors* and adverse drug incidents. The WHO emphasizes that the dangers of preventable treatment still occur across various levels of health services, including in low- and middle-income countries. This condition requires the development of an approach that is able to detect risks early and provide recommendations quickly and accurately (World Health Organization [WHO], 2024).

In this context, clinical pharmacy services are strategically positioned because pharmacists are responsible for drug reconciliation, prescription review, identification of drug-related problems, monitoring of therapeutic responses, and prevention of side effects. However, the increase in the number of patients and the volume of clinical data often outweigh the capabilities of manual processing. AI can support pharmacists through clinical decision support systems, predictive modeling, *natural language processing*, and machine learning. The technology enables high-risk prescription screening, detection of inappropriate drug-use patterns, prediction of patients prone to side effects, and preparation of therapy recommendations based on individual patient characteristics (Ranchon et al., 2023; Hu et al., 2024).

While it offers great benefits, the application of AI in clinical pharmacy services has not yet yielded consistent evidence. Several studies show that AI can reduce the burden of warnings, identify inappropriate prescriptions, and predict adverse drug events. However, many technologies are still being developed in experimental settings or based on retrospective data from a single institution. Graafsma et al. (2024) found that only a small percentage of AI-based alert systems have been implemented in hospital practice, and there has been no external validation in the studies they reviewed. This shows a gap between the algorithm's technical performance and its effectiveness in daily service practice.

Research problems also arise from the diversity of algorithms, data sources, populations, service contexts, and safety indicators used. Some studies assessed accuracy, sensitivity, specificity, or *areas under the curve*, while others assessed reductions in prescribing errors, warning burdens, pharmacist interventions, or patient clinical outcomes. These differences make it difficult to compare research results and to draw strong conclusions about the most effective AI technology. In addition, data quality, algorithmic bias, clarity of recommendations, protection of patient data, professional responsibility, and the risk of overreliance on automated systems remain implementation issues that need to be considered (WHO, 2021, 2023).

Previous research has generally addressed AI in pharmaceutical practice broadly or focused only on specific applications, such as predicting side effects and optimizing drug alerts. Hatzimanolis et al. (2025) show that the use of AI in pharmaceutical practice remains more focused on workflow efficiency and productivity than on directly improving patient health outcomes. Studies that specifically integrate the form of AI application, the stages of the drug-use process, the role of clinical pharmacists, treatment safety indicators, evidence quality, and implementation obstacles remain limited. Thus, there is a *research gap*: a lack of a comprehensive synthesis explaining the extent to which AI truly contributes to treatment safety in clinical pharmaceutical services.

The novelty of this research lies in the effort to integrate evidence on the use of AI across the entire range of clinical pharmaceutical services, including prescription, reconciliation, verification, dispensing, drug administration, therapy monitoring, and side-effect reporting. This systematic review not only evaluates the types and performance of AI technologies but also maps their impact on mistreatment, adverse drug incidence, the quality of pharmacist interventions, and patient safety. In addition, the study identified implementation factors, including external validation, algorithm clarity, readiness of pharmaceutical personnel, system integration, data governance, and human supervision. This approach offers incremental novelty through a conceptual framework that links AI capabilities to *pharmacists' professional roles* and treatment safety outcomes.

This research is urgent because the adoption of AI in healthcare is outpacing the development of clinical evidence, ethical guidelines, and regulatory systems. Without systematic evaluation, the application of AI risks producing irrelevant warnings, biased recommendations, poor decision-making, and a decrease in the trust of healthcare professionals and patients alike. Therefore, this study aims to identify, evaluate, and synthesize scientific evidence on the use of AI to improve treatment safety in clinical pharmaceutical services. The results of the research are expected to serve as a basis for pharmacists, hospital managers, technology developers, and policymakers in implementing AI that is effective, transparent, and ethical, while still positioning pharmacists as the primary professional decision-makers (Alqahtani et al., 2025; WHO, 2023).

METHOD

This study employs a systematic literature review to identify, evaluate, and synthesize research on the use of artificial intelligence to improve treatment safety in clinical pharmacy services. The research process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, which include the stages of identification, screening, feasibility assessment, and article selection (Page et al., 2021). Article searches were conducted in the Scopus, PubMed, Web of Science, and ScienceDirect databases for publications from January 2020 to July 2026. The search strategy uses a combination of keywords and Boolean operators: ("artificial intelligence" OR "machine learning" OR "deep learning" OR "natural language processing") AND ("medication safety" OR "medication error" OR "adverse drug event" OR "drug-related problem") AND ("clinical pharmacy" OR "pharmaceutical care" OR "pharmacist"). Search strategies and stages are reported transparently so that they can be replicated according to the PRISMA-S guidelines (Rethlefsen et al., 2021).

Inclusion criteria include empirical research articles that have gone through a *peer review* process, are available in full text, use English or Indonesian, and discuss the application of AI in the prevention of medication errors, drug interaction detection, prediction of side effects, dose optimization, clinical warning systems, or decision-making by pharmacists. Articles in the form of editorials, comments, conference abstracts, protocols, duplications, and research not directly related to clinical pharmacy services were excluded from the analysis. Article selection was carried out by examining titles, abstracts, and full texts, while methodological quality was assessed using JBI critical appraisal instruments according to each study's design. The extracted data included authors, publication years, countries, study designs, populations, types of AI technology, data sources, roles of pharmacists, treatment safety indicators, key outcomes, and study limitations. Furthermore, data were analyzed using narrative synthesis and thematic analysis to classify the forms of AI utilization, clinical benefits, accuracy levels, implementation barriers, and implications for patient safety. The synthesis approach is tailored to the diversity of designs, methods, and research outputs found (Aromataris et al., 2022).

RESULTS AND DISCUSSION

Results

The results of the literature synthesis show that the use of *artificial intelligence* in clinical pharmacy services can be grouped into four main areas, namely prescription review and verification, prediction of the risk of medication errors, optimization of drug warning systems, and monitoring of side effects and patient therapy outcomes. The most widely used technologies are *machine learning*, *deep learning*, *natural language processing*, and AI-based clinical decision support systems. Most models are developed using electronic medical record data, prescription data, laboratory test results, patient characteristics, disease history, and pharmacist intervention documentation. Prescription review is the area most often targeted by AI development because the process involves large volumes of data and requires rapid identification of improper doses, duplication of therapy, contraindications, drug interactions, as well as drug selection that is not appropriate for the patient's condition (Ranchon et al., 2023; Johns et al., 2024).

Subsequent findings suggest that AI can help pharmacists prioritize high-risk patients and prescriptions. Machine learning-based models can group patients based on the likelihood of experiencing drug mismatches when admitted to the hospital so that drug reconciliation can be focused on patients who need it most. Abdo et al. (2024) reported that the *voting classifier* model identified patients with drug mismatches more effectively than the previously used selection instruments. In the prescription review process, the Light Gradient Boosting Machine model also showed greater ability than the random forest in predicting prescriptions that require pharmaceutical intervention, particularly in terms of accuracy, precision, specificity, and *area under the curve*. The findings show that AI can be a clinical triage tool to improve the scope of prescription reviews without replacing the professional evaluation of pharmacists (Abdo et al., 2024; Johns et al., 2025).

AI also shows potential in detecting medication errors in high-risk patient groups and optimizing clinical alert systems. In patients in neonatal intensive care units, *machine learning models* that combine work environment characteristics and pharmacotherapy parameters can predict errors in the prescribing, setup, administration, and monitoring stages for high-performance drugs. Meanwhile, the application of AI to *clinical decision support systems* can help reduce the number of irrelevant alerts, improve the

identification of unusual or inappropriate prescriptions, and predict the likelihood that healthcare workers will receive or ignore an alert. Despite the promising results, most of these warning models are still developed using data from a single institution and have not undergone adequate external validation (Yalçın et al., 2023; Graafsma et al., 2024).

In terms of service outputs, the integration of AI with pharmacist-led services has the potential to improve the accuracy of prescriptions, increase the acceptance of pharmacist recommendations, reduce the incidence of drug side effects, shorten the duration of treatment, and reduce treatment costs. Li et al. (2025) found that a random forest-based prediction model integrated into the prescription optimization service for surgical patients increased acceptance of pharmacist recommendations and improved several service outputs. However, the results of the evaluation of generative AI show that the performance of the technology varies according to the model and type of task. Generative AI can provide good answers in drug consultation and education, but it still fails to recognize important contraindications, adapts recommendations to local guidelines with limitations, and makes reasoning errors in complex cases. Thus, generative AI cannot yet serve as a sole basis for clinical pharmaceutical decision-making (Li et al., 2025).

Discussion

The results show that the main contribution of AI to medical safety does not lie in replacing pharmacists, but in improving pharmacists' ability to process data and recognize risks. AI can analyze thousands of prescription data and medical records in less time than manual assessments, while pharmacists provide clinical interpretations based on the patient's condition, therapeutic goals, patient preferences, and service context. The collaboration forms an *augmented intelligence approach*, which is a technology that expands professional capacity without taking over clinical responsibilities. These findings are in line with the study of Alqahtani et al. (2025), which places AI as a support system in the detection of side effects, clinical decision-making, therapy personalization, pharmacometrics, and improved patient adherence.

AI's ability to prioritize high-risk patients has important implications for the efficiency of clinical pharmacy services. The limited number of pharmacists means that not all patients can obtain medication reconciliation and in-depth therapy reviews. Predictive models allow resources to be directed to patients with polypharmaceuticals, complex comorbidities, impaired kidney or liver function, a history of side effects, and high-risk drug use. The use of AI models can thus expand the range of pharmacist interventions while reducing the time spent assessing low-risk prescriptions. However, the sensitivity of the model needs to be balanced with its precision so that the system does not miss patients who are actually at risk or produce too many false positive results (Abdo et al., 2024; Johns et al., 2025). AI also has the potential to overcome *alert fatigue* that often appears in rule-based decision support systems. Too many and less relevant alerts can cause healthcare workers to ignore notifications, including clinically important alerts. AI models can study alert reception patterns, patient characteristics, drug combinations, laboratory results, and clinical context to determine notification priority. However, reducing alerts should be done with caution as misclassification can cause important warnings to not be displayed. Therefore, each system needs to establish clear risk limits, provide audit mechanisms, document the reasons for warning screening, and allow pharmacists to review algorithmic decisions (Graafsma et al., 2024).

The main limitation of the current evidence is the heterogeneity of the data, algorithms, populations, and output indicators used. The Johns et al. (2024) study showed that most studies of inaccurate prescription prediction models have a high risk of bias, while dataset sizes and data collection periods vary widely. Models that have high accuracy on internal data may not necessarily show the same performance when used in different hospitals, countries, populations, or medical record systems. Other problems include incomplete data, imbalances in the number of cases, changes in prescribing patterns, bias against certain groups of patients, and low clarity of reasons behind model recommendations. External validation, prospective testing, recalibration, and periodic performance monitoring are required before a system is widely implemented (Johns et al., 2024; Graafsma et al., 2024).

Based on these findings, the implementation of AI in clinical pharmacy services needs to be based on the principles of *human-in-the-loop*, transparency, data security, and professional accountability. The system must be integrated with electronic medical records, be easy to use, be able to explain factors influencing recommendations, and not add to the pharmacist's documentation burden. Future research

needs to use a prospective design of multicenter or controlled clinical trials to assess the impact of AI on preventable medication errors, adverse drug incidence, mortality, length of treatment, cost, workload, and patient satisfaction. Additionally, there is a need for ongoing evaluation of generative AI as model updates can change the quality of its answers. Thus, safe AI in clinical pharmacy is one that has been validated, pharmacist-supervised, adapted to local guidelines, and used as a decision supporter, not as an independent decision-maker (Alqahtani et al., 2025; Li et al., 2025)

CONCLUSION

The use of *artificial intelligence* in clinical pharmacy services shows great potential to improve treatment safety. AI technologies, such as *machine learning*, *deep learning*, *natural language processing*, and clinical decision support systems, can help identify risky prescriptions, detect drug interactions and mismatches, predict side effects, prioritize high-risk patients, and reduce irrelevant clinical warnings. The application of such technology can also improve pharmacists' work efficiency and expand the scope of therapy reviews, especially in healthcare services with high patient volumes and large volumes of clinical data. Nonetheless, the effectiveness of AI in improving clinical outcomes has not been completely consistent. Most models are still developed using retrospective data from a single institution, have a risk of bias, and have not undergone extensive external validation or prospective testing. Differences in algorithm types, data sources, populations, and safety indicators make it difficult to compare the results of the study directly. In addition, issues of data quality, algorithm transparency, patient privacy, technology bias, system integration, and professional responsibility remain major challenges in AI implementation. Based on the results of a systematic review, AI should be positioned as a decision-support tool rather than a substitute for pharmacists. A *human-in-the-loop approach* is necessary to ensure that each algorithm's recommendations are evaluated in light of the patient's clinical conditions, individual needs, and preferences. The success of AI applications in clinical pharmacy services depends on the quality of the technology, pharmacists' digital competence, organizational readiness, and the availability of a governance system that ensures security, transparency, and accountability. With the right implementation, AI can support the formation of clinical pharmacy services that are more predictive, personalized, efficient, and patient-safety-oriented.

Suggestions

Future research is suggested using a prospective, multicenter, and controlled clinical trial design to evaluate the impact of AI on medication errors, adverse drug events, treatment duration, mortality, cost of care, and patient quality of life. AI models also need to be tested across different populations, institutions, and health systems to ensure external validity and generalizability. Research needs to assess not only technical accuracy but also clinical effectiveness, cost-efficiency, user acceptance, and the impact on the relationship between pharmacists and patients. Healthcare institutions are advised to implement AI gradually through limited trials, local validation, periodic audits, and monitoring of algorithm performance. The system used must be integrated with electronic medical records, easy to understand, able to explain the basis of recommendations, and provide a correction mechanism by the pharmacist. The development of operational guidelines, patient data protection, responsibility-sharing mechanisms, and system error-reporting mechanisms is also required before large-scale implementation. Pharmacists need to improve competencies in data literacy, health informatics, algorithmic evaluation, digital ethics, and interpretation of AI outputs. Colleges and professional organizations are advised to integrate AI materials and digital health technologies into clinical pharmacy education and training. Governments and regulators also need to develop standards for validation, certification, data security, transparency, and AI supervision in pharmaceutical services. Collaboration between pharmacists, doctors, data scientists, technology developers, patients, and policymakers is an important factor for the application of AI to be able to improve the safety of treatment in a sustainable manner without reducing the professional role and clinical considerations of humans.

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