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The Rise of Artificial Intelligence in Pharmacy: Transforming Medication Management and Patient Care

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Abstract

Artificial intelligence (AI) is rapidly transforming healthcare, with significant implications for pharmacy practice. This review explores the diverse applications of AI in pharmacy, emphasizing its potential to revolutionize medication management, patient care, public health, disease management, and pharmacy workflow efficiency. AI algorithms can analyze a vast amount of patient data, allowing pharmacists to identify potential drug interactions, evaluate medication safety and effectiveness, and offer personalized treatment suggestions. In the realm of public health, AI supports disease management through epidemiological monitoring and targeted interventions. Additionally, AI-driven robotic dispensing systems and automated inventory management enhance pharmacy workflow efficiency by streamlining operations and optimizing resource allocation. Telepharmacy, further augmented by AI, is revolutionizing remote healthcare by improving accessibility, efficiency, and patient outcomes. Despite these advancements, challenges such as data privacy and potential bias in AI algorithms persist. However, the potential of AI in pharmacy is undeniable. By addressing these challenges and fostering collaboration among pharmacists, AI developers, and regulatory bodies, the future of pharmacy is poised to deliver personalized care, improved patient outcomes, and enhanced public health. This integration of AI into pharmacy practice represents a significant step toward a more effective and patient-centered approach to healthcare.

Keywords: Artificial intelligence (AI), pharmacy practice, healthcare

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Introduction

Artificial Intelligence (AI) is a field within computer science where we develop problem-solving techniques through symbolic programming. Over time, it has developed into a comprehensive science of problem-solving with extensive applications in fields such as engineering, business, and healthcare. With AI, fueled by advancements in machine learning and data analytics, we are entering another new age of automation, efficiency improvements and intelligent decision-making[1].

In recent years, AI has already shown tremendous potential in revolutionizing healthcare in ways no one could have predicted; some of which are medical record keeping, treatment preparation and system auditing. The main goal of the application fields in health is to identify whether there are links between patient outcomes and different prevention or therapy approaches. This technological advancement has led to enhanced diagnostic accuracy, more efficient workflows for healthcare providers, and significantly improved patient outcomes[2].

As compared to people, AI can accomplish some activities faster and more accurately. Pharmacists can use AI and machine learning to analyze large amounts of patient information including, but by no means limited to medical history records, lab results and even their medication profile. AI refers to intelligence that is provided so that results of clinical trials can be better in a significant manner. This allows them to determine whether a drug has potential interactions, evaluate the safety and efficacy of a medication, and deliver tailor-made recommendations on patients. The potential of AI in pharmacy practice is vast, and applications cover an array of medication management, inventory control, and patient education opportunities[3].

Significant potential is seen in AI application across many frontiers of pharmaceutical practice. In the same way, even though there is much promise in its use of AI technology, to develop it fully will still require filling research gaps. The most crucial element is comprehending the influence of AI services on financial and clinical results and fully implementing them within current pharmaceutical systems[4]. This review delves into the exciting world of AI applications in pharmacy practice. We will explore the current landscape and needs as well as outline some promising future directions for AI in this field, while also analyzing gaps in research.

Methods

To determine the scope of this narrative review, we searched PubMed, Google Scholar, and Scopus for relevant articles. We employed various search terms to locate relevant articles. which included "Artificial intelligence," "Pharmacy practice", "Medication Management", "Patient Care", "Public Health and Disease Management", "Pharmacy Workflow and Efficiency", and "Telepharmacy". We reviewed the reference lists of relevant articles to identify other potentially significant papers on the subject. The journals were screened with inclusion criteria of articles related to AI in pharmacy and published in 2014-2024, as well as exclusion criteria of repository and review articles.

Results and Discussion

Medication Management and Patient Care

Pharmacists have the opportunity to utilize AI algorithms to analyze a patient's medical history, current prescriptions and the extent of allergic reactions. This significantly reduces medication errors, improves patient safety, and prevents adverse outcomes. For instance, pharmaceutical order reviews can be

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optimized using machine learning algorithms to identify inappropriate prescriptions that require reevaluation by clinical pharmacists[5]. AI's ability to detect deviations early allows for quick intervention, reducing adverse reactions and enhancing patient safety through comprehensive medication management[4].

While pharmacist-led interventions are effective in improving medication adherence, they often involve complex processes. AI technology offers a promising solution by addressing multiple barriers to adherence[6]. AI can track patient habits, refill patterns, and medication history to identify factors leading to non-adherence, ultimately improving adherence rates and treatment outcomes[7]. Furthermore, AI is transforming pharmacy operations by automating routine tasks, allowing pharmacists to focus more on patient care. The Robotic Dispensing System in Community Pharmacies, for example, automates the selection, packaging, and labeling of medicine, enhancing accuracy and speed while freeing up pharmacists to provide direct patient care. These AI-driven advancements are poised to revolutionize pharmacy practice, promoting medication adherence, improving patient safety, and streamlining workflows for better health outcomes[8].

Another example is IBM Watson, a powerful computer that uses AI and advanced analytics to answer questions. Watson for Oncology is designed to help doctors make better decisions in cancer treatment by analyzing a patient's medical data and offering care options based on an extensive and growing network of experts. Watson draws from over 200 textbooks, 12 million text pages, and 290 medical periodicals, as well as literature and findings, giving it access to a vast reservoir of knowledge[1].

Public Health and Disease Management

AI algorithms can analyze patient data in real time as well as pharmacy dispensing records to identify patterns and likely infectious disease outbreaks. For instance, the BlueDot AI system effectively tracks outbreaks based on travel patterns and medication purchases. This continuous surveillance allows public health systems to intervene early, reducing disease spread and protecting lives[9].

Historical analysis of social media activity regarding epidemics followed by highly accurate prediction of epidemic location and timing are made possible by AI. Consider a future where AI notifies pharmacists about potential outbreaks in their locality so they could immediately advise patients, liaise with other healthcare officers from the local department of health among others. This collaboration between AI and pharmacists enhances their ability to uncover hidden trends and improve medical care[3].

Beyond that, AI can help pharmacists in addressing issues of health inequities by looking up such data as zip codes, demographics, and medical histories. By pinpointing areas with significant socioeconomic differences, AI can recommend targeted interventions. For example, AI could identify regions with high diabetes rates, leading to educational programs, free drug distribution, or improved access to care[10].

Pharmacy Workflow and Efficiency

Computerized Prescriber Order Entry (CPOE) is a system that provides a digital platform for doctors to enter and send medical orders, including those for medications, laboratory tests, admissions, radiology, and procedures, instead of using manual methods. This reduces errors from illegible handwriting and transcription mistakes. CPOE systems manage medication histories and electronically transmit orders to pharmacists, enhancing patient safety[11].

AI-powered robotic systems can greatly automate repetitive tasks like inventory management or medication dispensing activities. By analyzing historical data, AI can predict medication demand and optimize stock levels, helping avoid stockouts and allowing pharmacists to focus on critical tasks[6]. Pharmacist can optimize their inventory management by using artificial intelligence in analyzing historical sales data, patient demographics and seasonal trends to predict future drug demand with higher accuracy. It ensures that pharmacies have enough stock on hand to meet patient needs while minimizing the risk of expired medications. This automation streamlines pharmacy operations, reduces errors, and frees up pharmacists to focus on patient care[12].

Telepharmacy

Telepharmacy is an innovative approach that utilizes telecommunication and technology to provide remote pharmacy services, meeting the increasing demand for accessibility, convenience, and cost-effectiveness in healthcare. The integration of artificial intelligence into these systems has the potential to significantly elevate the quality of telepharmacy services, offering improved patient outcomes, especially in underserved and rural communities[13]. For instance, chatbots with natural language understanding can speed up the process of gathering patient history by asking questions and offering prompts tailored to the patient's answers. These chatbots can also identify potential diagnoses, such as adverse drug events, and record them for future reference[14].

Integrating ChatGPT into telepharmacy services offers considerable potential. ChatGPT exhibits the capability to simulate the role of a telepharmacist effectively, maintaining a professional persona while handling patient inquiries. It follows commands accurately, understands complex case details, and offers precise, mostly accurate answers to medication-related questions. Additionally, it delivers responses that are consistently clear, concise, and sufficiently comprehensive, enhancing its usefulness in virtual healthcare settings where precision and clarity are vital[15]. The summary of findings is shown in Table 1.

Challenges and Limitations

Despite numerous benefits of AI to pharmacy practice, it has some difficulties and limitations. It is crucial for these concerns to be addressed in order to ensure ethical and responsible AI implementation in pharmacy. AI algorithms rely on huge chunks of patient data. This sensitive information must always be secured through privacy and security measures at the pharmacies that handle it. Besides, regulatory frameworks cannot keep pace with the rapid development of AI technologies. Efficacious, safe and ethical use of AI in healthcare requires clear and consistent regulations. Proper regulatory frameworks must be established through collaboration between regulatory bodies, healthcare providers, and AI developers for use of AI in pharmacy[29].

Data collection biases used in training AI models have the potential to generate biased outcomes. For instance, minorities may be underrepresented by datasets created with racial bias in dataset creation, therefore, lower prediction error rate than expected may occur. If there is an underlying bias and inequality within the healthcare system, even when the AI systems are trained with correct and representative data problems can arise[30].

The next hurdle is AI development that follows data acquisition. Overfitting occurs when the AI system learns irrelevant relationships between patient variables and outcomes. This problem arises when there are too many variables compared to the outcomes, leading to inaccurate predictions due to the use of inappropriate algorithm features. Algorithms like classification and clustering might demonstrate high accuracy with limited data, but this performance may not be reliable in real-world situations. Furthermore, one of the most difficult challenges in medical data processing is the need to combine text, numerical, image, and video data into a single algorithm[31].

Although a few barriers were noted, pharmacists showed a positive attitude toward working with AI. These emphasize the importance of creating learning programs that will enhance pharmacists' knowledge about artificial intelligence while also providing enough financial support in order to overcome the challenge of high operational costs for implementing this into practice. Technical assistance can help pharmacists get over not having sufficient AI software and technology. By doing this, community pharmacies can have better integration of AI technology hence enhancing patient care and health outcomes[32].

Conclusion

Artificial intelligence's positive influence on the pharmacy sector holds great promise for patients and pharmacists. AI tools empowered by AI can allow personalized care plans, increase or improve patients' adherence to medications and give pharmacists more time for improving patient consultations. As AI becomes more collaborative with pharmacists, it will be possible to create a better performing medical system that is more centered around the patient. However, this future needs to be approached cautiously if at all. Issues of data privacy and security issues, possibilities of biased algorithms in AI as well as dealing with legislations have to be dealt with first. There should be open channels of communication between the pharmacists, developers of this technology and regulatory bodies involved. The use of Artificial Intelligence within Pharmacy can only be ethical if carried out collectively yet effectively while prioritizing the welfare of patients in all instances.

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Conflict of Interest

None declared.

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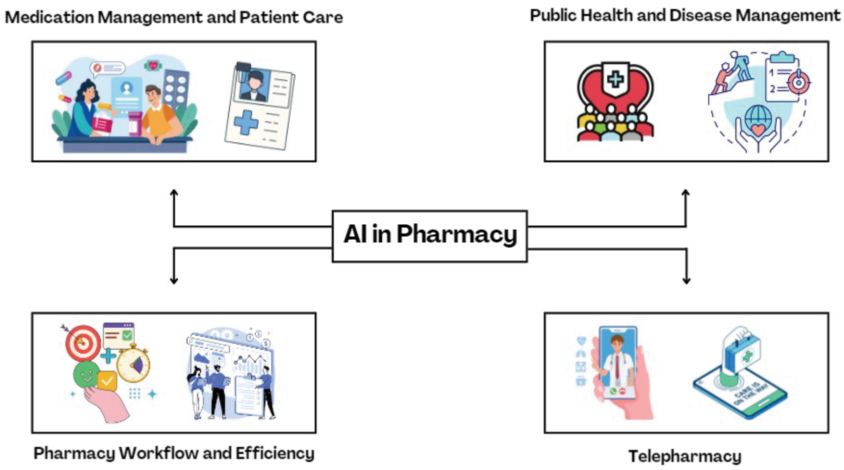

Figure 1. The Role of AI in Modern Pharmacy

Table 1. Study Characteristics and Main Findings of Implementation of AI Applications in Pharmacy Practices

Author, year	Country	Study design	Type of AI	Objectives and Main findings
Takase et al, 2022[8]	Japan	Experimental and statistical analysis	Robotic dispensing systems	This study aims to evaluate the impact of robotic dispensing systems and collaborative work with pharmacy support staff on medication dispensing. The overall rate of prevented dispensing errors significantly dropped from 0.204% to 0.044%. Likewise, the rate of unprevented dispensing errors saw a marked reduction from 0.015% to 0.002%. Errors related to incorrect drug strength and wrong medications, which pose serious health risks, were almost entirely eliminated. Moreover, the median dispensing time per prescription for pharmacists was significantly reduced, from one minute to just 23 seconds.

Blasiak et al, 2022[16]	Singapore	Prospective feasibility trial	CURATE.AI, an AI-driven platform that leverages a patient's own prospectively or longitudinally collected data to dynamically determine their optimal personalized dosing.	The objective of this study is to evaluate the feasibility of conducting prospective trials for CURATE.AI, aid in hypothesis formulation, identify potential risk factors, and support the design of these trials. On average, the prescribed dose was reduced by 20% (±13.8%) compared to the projected standard of care (SOC) dose. Among the nine patients involved, the average number of completed cycles was 3.9 (±2.2 cycles), with the longest duration being 8 cycles. Out of 40 total dosing decisions, CURATE.AI recommendations were considered in 27 cases, with 26 of those being accepted for prescription.
Momattin, et Al, 2021[17]	Saudi Arabia	Data collection	Robotic Pharmacy	This study is designed to improve efficiency, reduce medication dispensing errors, enhance patient satisfaction, and allow pharmacists more time for direct patient consultations. The average wait time decreased by 53%, patient satisfaction with pharmacy wait time increased by 20%, and overall satisfaction with pharmacy services rose by 22%. Additionally, pharmacist productivity increased by 33%. The dispensing process was error-free.

Rodriguez-Gonzalez et al, 2019[18]	Spain	A prospective before-and-after design using disguised observation.	Robotic dispensing system	This study explores the frequency of medication dispensing errors before and after introducing a robotic original pack dispensing system in an outpatient hospital pharmacy, along with its effects on stock management quality and staff satisfaction. The medication dispensing error rate decreased from 1.31% (43 errors out of 3,284 prescriptions) to 0.63% (19 errors out of 3,004 prescriptions), leading to a relative risk reduction RRR) of 51.7%. When excluding errors from residual manual dispensing, the error rate further dropped to 0.12% (3 out of 2,496), with an RRR of 90.8%. The daily median time spent by staff on stock management was reduced by 59.3%, from 96 minutes to 39 minutes.
Thapen, 2016[19]	United Kingdom	Retrospecti-ve design	DEFENDER, a software system for outbreak detection and forecasting.	This study aims to develop and evaluate a data-driven system for early detection and forecasting of epidemics. The DEFENDER system demonstrated significant potential for early detection and forecasting of epidemics. Using symptoms along with previous case data improved the accuracy of our predictions by 37% compared to a model that only used previous case data.
Rolland et al, 2020[20]	United States and France	Retrospecti-ve design	ProMED-mail, a global online disease reporting system	This study is designed to assess the effectiveness of ProMED-mail in detecting public health emergencies of international concern. Of the undiagnosed disease events described in ProMED-mail, 6.5% (24 out of 371) were reported in the Disease Outbreak News. The median delay between the first ProMED-mail notification and the corresponding Disease Outbreak News publication was 18.5 days, with a range from -1 to 254 days.

Surya et al, 2020[21]	Global	Predictive modeling and data-driven analysis study	Bluedot, AI model that provides intelligence on infectious diseases	The objective of this study is to predict humans by spotting infectious disease outbreaks. On December 31, 2019, the Canadian health monitoring company BlueDot issued an early alert about the COVID-19 outbreak in China and its potential global spread—nine days before the World Health Organization made its public announcement. BlueDot also leveraged global air travel data to predict the cities and countries most at risk. The first locations affected by the virus were among the top 11 countries identified by BlueDot.
Puca et al, 2020[22]	Global	Descriptive epidemiolo-gical study	EpiWATCH, intelligence surveillance tool	This study aims to identify information about the number of confirmed/probable/suspected mumps cases and also the date, country, and location of outbreaks. EpiWATCH recorded 65 mumps outbreaks worldwide and detected reported mumps cases within days of news outlets releasing the information, much faster than the months it usually takes for validated sources to publish such data. EpiWATCH identified mumps outbreak data that had not been previously detected by the WHO or CDC.

Jungreith-mayr et al, 2021[11]	Germany	Comparati-ve study	Computerized physician order entry (CPOE) system	The purpose of this study is to explore the specific impact of implementing a CPOE system in general wards of a large tertiary care hospital on the quality of prescription documentation. The overall mean prescription F-score, which measures adherence to 20 criteria, rose significantly from 57.4% ± 12.0% (based on 1,850 prescriptions) before the system was implemented to 89.8% ± 7.2% (based on 1,592 prescriptions) after im-plementation.
Segal et al, 2019[23]	Israel	Prospective study	Machine-learning based clinical decision support system	This study is designed to evaluate the accuracy, effectiveness, and practical value of medication error warnings produced by a new system that uses abnormal data detection methods. The system had a low alert burden, with warnings issued for only 0.4% of all medication orders. Of these alerts, 60% were triggered after the medication had already been administered. The alerts were found to be 85% accurate and 80% helpful, with 43% of them resulting in changes to subsequent medical orders.
Laustalot et al, 2019[24]	France	Prospective observation-nal study	Computerized physician order entry (CPOE) system	The objective of this study is to evaluate the clinical interventions made by pharmacists, particularly the acceptance of these interventions, issues related to CPOE, and their potential impact on patient safety. CPOE-related errors accounted for 14.7% of the total errors, a significant improvement compared to the 49% reported a decade earlier.

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Bu et al, 2022[25]	China	Perspective based on a case study	AI-based medication consultation	The objective of this study is to establish an internet hospital pharmacy service model based on AI and to offer new insights into pharmacy services in internet hospitals during the COVID-19 pandemic. A total of 426 medication consultations were provided, with 48.83% occurring outside of regular working hours. Consequently, an AI-based medication consultation service was proposed for times when pharmacists were unavailable.
Roy et al, 2023[26]	USA	Pilot investigation using data from two Phase II clinical trials	AiCure, a computer vision-assisted mobile application, to monitor medication adherence in patients.	The purpose of this study is to enhance patient retention and the quality of clinical trial data. In one of the trials, 43% of participants were found to be less than 80% compliant with their medication regimen. The model successfully identified high-risk patients with low adherence, with the 14-day monitoring period model offering the most accurate predictions and a lower false omission rate.
Jennifer et al, 2023[27]	USA	Comparati-ve evaluation study	Chatbot focused on medication guidance	This study aims to evaluate the clinical completeness, accuracy, usefulness, and safety of responses provided by a chatbot and a medication database to common inpatient medication-use queries. The medication database answered 194 (97%) of the questions, with 88% being clinically correct, 76% sufficiently complete, 83% safe, and 81% useful compared to pharmacists' responses. In contrast, the chatbot responded to 160 (80%) of the questions, with 85% deemed clinically correct, 65% sufficiently complete, 71% safe, and 68% useful.

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Daniel et al, 202228	France	Proof-of-concept study	Chatbot using IBM's Watson API combined with a custom dictionary.	The objective of this study is to develop and implement an artificial intelligence (AI) chatbot to provide answers to questions from hospital caregivers about drugs and pharmacy organization. The chatbot received good evaluation scores, which are speed: 8.2 out of 10, usability: 8.1 out of 10, and appearance: 7.5 out of 10. Seven key themes were identified, including queries about opening hours and specific prescriptions. 70% of testers were generally satisfied with the chatbot.