



**INTERNATIONAL JOURNAL OF
PHARMACEUTICAL SCIENCES**
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: <https://www.ijpsjournal.com>



Review Article

Beyond Dispensing: AI Empowering Clinical Pharmacist

Darshana Sunil Nagmoti¹, Khode Aniket Prakash^{*2}, Netra Nitin Marathe³, Harsh Santosh Jadhav⁴, Tanuja Wankhede⁵

^{1,3,4}MGV'S Pharmacy College, Panchavati, Nashik- 422003, Maharashtra, India.

²School Of Pharmaceutical Sciences, Sandip University, Nashik- 422213, Maharashtra, India.

ARTICLE INFO

Published: 13 Oct 2025

Keywords:

Artificial Intelligence,
Clinical Pharmacy, Adverse
Drug Events, Clinical
decision support system

DOI:

10.5281/zenodo.17336807

ABSTRACT

The integration of artificial intelligence (AI) into clinical pharmacy marks a transformative shift from traditional dispensing roles toward proactive, patient-centered care. This article explores how AI technologies—particularly natural language processing (NLP), machine learning (ML), and deep learning (DL)—can enhance pharmacists' ability to manage complex pharmacotherapy, improve medication safety, and personalize treatment. With aging populations and rising multimorbidity, clinical pharmacists face increasing challenges in polypharmacy, adverse drug events (ADEs), and therapeutic optimization. AI-powered tools such as clinical decision support systems (CDSS), predictive analytics, and pharmacogenomic modeling offer scalable solutions to these issues by enabling early risk detection, regimen simplification, and real-time decision-making. The review highlights AI's role in telepharmacy, antimicrobial stewardship, diabetes care, and patient engagement, emphasizing its potential to automate routine tasks while preserving human judgment for nuanced decisions. Ethical, legal, and professional considerations—including data privacy, bias mitigation, and accountability—are addressed to ensure responsible implementation. Ultimately, AI is positioned not as a replacement but as a force multiplier that empowers pharmacists to deliver safer, more efficient, and personalized care.

INTRODUCTION

There has been a major professional revolution in pharmacy as a result of the modern pharmacist's scientific administration of increasingly sophisticated pharmacotherapy, which has

replaced the apothecary's artisan compounding based on plant knowledge. Pharmacists' everyday responsibilities evolved from preparation to product selection and distribution over the 20th century due to industrial manufacture and restrictions. However, the clinical pharmacy practice paradigm gained popularity in the latter

***Corresponding Author:** Khode Aniket Prakash

Address: School Of Pharmaceutical Sciences, Sandip University, Nashik- 422213, Maharashtra, India.

Email : aniketkhode3715@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



half of the century. This method prioritizes the patient over the product and maximizes treatment outcomes through direct care, teamwork, and evidence-based decision-making [1]. The pharmaceutical care concept, which maintains that "the responsible provision of drug therapy for the purpose of achieving definite outcomes that improve a patient's quality of life" is the aim, was finally adopted, strengthening it. This viewpoint continues to define the profession's social contract and quantifiable contributions to safety, efficacy, and value[2]. Legislation enacting this change has been passed by regulatory bodies. According to the American College of Clinical Pharmacy (ACCP), clinical pharmacy is a branch of medicine in which pharmacists treat patients to maximize therapeutic advantages while promoting wellness, illness prevention, and good health. This method involves the use of medications and calls for caution and specialized therapeutic skills. In essence, this way of thinking is "the science and practice of rational medication use." Since these concepts are frequently discussed in training and certification, clinical pharmacy is situated within interprofessional care models that place a high priority on outcomes, safety, and cooperative decision-making [3,4]. The need for clinical pharmacy that is focused on the patient has only increased. Demographically, populations are getting older, multimorbidity is rising quickly with age, and older adults are more likely to be polypharmacy. With multimorbidity prevalence in older groups often $\geq 80\%$ in population-based cohorts, WHO projects that the worldwide share of people aged 65 and over will quadruple between 2010 and 2050, with those aged 80 and over expanding even faster across OECD countries. Similarly high rates of polypharmacy have been found in national studies, which show that a significant percentage of older individuals have chronic exposure to five or more chronic drugs, and a similar percentage have hyper-

polypharmacy (using more than ten medications). Clinical pharmacists' expertise in benefit-risk weighing, deprescribing, and adherence facilitation is well-suited to address these trends, which increase the likelihood of improperly targeted prescribing, adverse drug events (ADEs), and costly downstream use [5,6]. Medication safety is a top priority on a global scale. Drug Without Harm: The WHO Global Patient Safety Challenge Coordinated, system-level efforts are required to cut the number of serious, preventable medication-related injuries in half, as drug errors are estimated to cost the global economy \$42 billion annually [7]. Every year, hundreds of millions of pharmacological errors that lead to avoidable adverse drug events (ADEs), hospitalizations, and unnecessary deaths are believed to be caused by communication breakdowns during care transitions. Clinical pharmacists' roles in treatment evaluation, team communication, patient education, and reconciliation quickly address these areas of failure [8]. The role of clinical pharmacists is being supported by more and more facts. Pharmacy-provided medication reviews, care transitions, and longitudinal care improve disease risk-factor control of chronic diseases and reduce hospital readmissions for all reasons, including heart failure hospitalizations, according to recent assessments and systematic reviews. In hospital-based data, it has been shown that clinical pharmacists who conduct medication reconciliations, circle with teams, and offer discharge counseling considerably reduce the frequency of avoidable adverse drug events (ADEs) [9]. These findings, which reallocate pharmacists' time to higher-value cognitive tasks, support the triple aims of improving patient and population health, reducing costs, and preserving provider well-being as health systems increasingly adopt value-based methods [10]. The digital transformation of healthcare has coincided with the rapid growth of automated dispensing



technologies, e-prescribing, and electronic health records (EHRs). Modern technology can help pharmacists avoid some process problems and human labor, but it also creates massive, dispersed streams of data that are difficult for doctors to instantaneously comprehend ^[11]. Even though the EHR contains drug knowledge, lab patterns, vitals, genomics, social determinants, and unstructured clinical notes, under typical workflow conditions, identifying the signal such as premonitory toxicity symptoms, adherence drift, or dangerous drug–condition combinations—often places an undue amount of strain on human cognition. Three branches of artificial intelligence (AI)—natural language processing (NLP), machine learning (ML), and deep learning (DL)—may be useful to clinical pharmacy ^[12]. AI is particularly strong at recognizing patterns within high-dimensional data, forecasting near-future risk, and extracting meaning from unstructured text. These strengths are increasingly being used in medication safety and management: CDS and appropriateness checking are two examples of clinical decision assistance. Apart from static drug-drug interaction warnings, AI-assisted CDS can also rank clinically relevant alerts, reduce alert fatigue, and contextualize risk (e.g., patient age, renal function, comorbidities, lab trends). Carefully tailored to the population and workflow, CDS reduces prescription mistakes and inappropriate prescribing in older persons, according to systematic reviews. In order to improve post-marketing safety monitoring, NLP/ML algorithms extract references to symptom, timing, drug, and causality indications from clinical notes. This raises the possibility of ADEs far earlier than spontaneous reporting. Significant progress has been made in identifying specific ADEs from unstructured EHR text and social media data, toward extensive pharmacist-in-the-loop surveillance systems, according to recent scoping and systematic reviews estimating the likelihood

of decline and readmission. Limited resources can be directed toward patients who stand to gain the most from prescription monitoring, early follow-up, and reconciliation by employing pharmacist-bundled risk models. Real-world studies have shown that early readmission rates are decreased when inpatient pharmacists prioritize at-risk discharges using predictive scores included into workflows ^[13].

AI can find intricate regimen networks, predict regimen simplifications to preserve efficacy while lowering burden, and detect possibly unsuitable drugs for a particular phenotypic or genotypic profile. These technologies are intimately linked to pharmacists' skills in therapeutic monitoring and patient counselling during multimorbidity. (See also OECD studies that associate age and polypharmacy with preventable expenses and harm) ^[14].

AI-powered tele pharmacy solutions can monitor adherence trends (such refill gaps and smart package signals) in decentralized therapy, evaluate symptom reports for triage, and notify a pharmacist when risk thresholds are exceeded. This notifies a pharmacist when risk thresholds are exceeded, automating daily observation but maintaining human judgment for complex decisions. According to surveys and mixed-methods studies conducted in various settings, pharmacists are enthusiastic about the promise of AI and tackling implementation difficulties such as infrastructure, training, ethics, and data quality ^[15].

Artificial intelligence (AI) systems predict response and toxicity to inform drug and dosage selection by integrating clinical, proteomic, and genomic data. As these models evolve, clinical pharmacists automatically adapt to genotype-directed therapy, monitoring, and patient education by converting AI results into



personalized regimens and team decisions. The journey from innovation to the patient's bedside is traced by in-depth assessments of pharmaceutical sciences ^[16].

Preliminary evaluations suggest that uncertainty-sensitive AI that generates confidence measures and encourages contestability may speed up and improve performance by identifying scenarios when AI is uncertain, encouraging expert supervision, and reducing automation bias. Creating decision support that enhances clinical judgment rather than takes its place is necessary for reliable implementation ^[17].

As anticipated by an OECD study, national governments and payers have rekindled their interest in drug safety economics due to the rising rate of polypharmacy among those aged 75 and beyond and the possible financial gains from reducing medication-related risk. AI has the potential to accelerate the WHO safety challenge's requirements for system redesign, measurement infrastructures, and learning health systems. Clinical pharmacists, who are privileged, competent, and part of diverse teams, will be well-positioned to lead these AI-enabled advancements as long as they continue to be advocates of evidence, equity, and patient confidence ^[18].

Practice to promise: current evidence and gap:

-

The use of AI for everyday clinical pharmacy is still in its infancy despite a rapidly expanding research base. Although NLP/ML summaries for ADE detection show strong technical performance, they also point to problems with workflow integration, disparate data sources, and a lack of external validation. Similarly, CDS can reduce the use of improper medication in older populations; but, in practice, its efficacy depends

on governance (curation, drift monitoring), usability (alert priority), and team adoption. Pharmacist-facing research shows that patient outcomes, including fewer preventable adverse drug events (ADEs) and early readmissions, improve when risk models and AI software are incorporated into rounding, discharge, and ambulatory care and specifically linked to pharmacist action (reconciliation, education, therapy optimization). The next phase will require comprehensive prospective assessments, human factors-driven design, and equity-sensitive rollouts to ensure AI supports pharmacists in all circumstances, not just in data-rich hospitals ^[19].

Implementation factors for clinical pharmacy:

-

In order for AI to actually empower clinical pharmacists from dispensing, a number of enablers are crucial:

- **Data quality and Interoperability:**

AI development is hampered by missingness, uneven programming, and disjointed systems. Pharmacists can assist with standardizing vocabularies, reconciling lists, and creating data pipelines that maintain context (indication, treatment goals) due to their extensive knowledge of the semantics of medication data. Governance, safety, and measurement. CDS is required to apply Medication Without Harm metrics, audit bias, and monitor model drift in addition to following regional formularies and renal/hepatic dose requirements. Pharmacists have the option to chair AI lifecycle management governance committees ^[20].

- **Cooperation between humans and AI:**

Reducing automation bias and increasing confidence can be achieved by interface design that highlights ambiguity, provides explanations,



and promotes pharmacist review. These characteristics have already been linked to quicker error detection and decision-making in preliminary testing^[21].

- **Accessibility and equity:**

Patients with polypharmacy, low health literacy, multimorbidity, and irregular access to technology must benefit from AI. Pharmacists may be in favor of language-specific training, universal databases, and outreach initiatives. (The WHO and OECD emphasize safety regulations that take equity into account.)^[22]

Purpose of this review: -

This study looks at how AI could improve pharmaceutical safety, efficiency, and personalization while also advancing clinical pharmacy's key ideals, such as patient care and rational therapy. We integrate the mechanistic opportunities (predictive analytics, NLP-based safety surveillance, AI-augmented CDS), chart the translational demands (data, governance, human factors) for responsible implementation across hospital, ambulatory, and community domains, and, when evaluated, rely on clinical impact. Essentially, we contend that rather than replacing clinical pharmacy, artificial intelligence (AI) is a force multiplier for pharmacists to achieve the promise of pharmaceutical care in an era of increasing complexity and limited resources^[23].

AI Integration in Clinical Pharmacy

1. AI as a Partner in Clinical Decision-Making:

Pharmacists have long benefited from clinical decision support systems (CDSS), which provide alerts for medication interactions, allergies, and dosage problems. However, these systems typically generate a large number of warnings,

which results in medical staff's weariness and attentiveness. By using machine learning (ML) algorithms that analyse vast amounts of data, including test results, patient demographics, and electronic health records (EHRs), AI enhances CDSS by providing personalized and context-aware recommendations^[24].

For instance, by identifying trends in patient data, AI may assist pharmacists in anticipating adverse drug reactions (ADRs) and taking prophylactic measures. By accounting for age, comorbidities, and renal function, AI can assist in optimizing medication dosage and enhancing therapeutic results^[25].

2. Personalized care according to pharmacogenomics:

Pharmacogenomics investigates how a person's genes affect how they react to drugs, potentially leading to more individualized care. By integrating genetic and clinical data, artificial intelligence (AI) enhances pharmacogenomics by predicting therapy efficacy and potential side effects.^[26] For example, AI can analyse genetic variations in drug-metabolizing enzymes using algorithms and recommend the optimal dosages to minimize the likelihood of adverse effects. By aiding in the selection of tailored medications based on the genetic profiles of the tumour, artificial intelligence (AI) can improve the effectiveness of cancer treatment^[27].

3. Predictive and Preventive Pharmacy:

Pharmacists can use AI's predictive analytics capabilities to predict prescription non-adherence, hospital readmissions, and adverse pharmacological events. By analysing patient data, AI can stratify risk and assist pharmacists in taking preventative action.^[28] By using machine learning algorithms to



determine which patients are most likely to stop taking their prescription medications, pharmacists may be able to take more prompt action and offer more assistance. AI can also predict likely drug interactions, allowing for quick adjustments to therapy^[29]

4. AI in Telepharmacy and Remote Care:

By automating procedures like medication counselling, adherence tracking, and follow-up assessments, artificial intelligence (AI) boosts the effectiveness of tele pharmacy. Pharmaceutical therapy can be delivered to remote locations thanks to telepharmacy. AI-enabled chatbots can remind patients to take their medications, respond to often asked queries, and provide prescription information. AI may analyze data from wearable devices to track patient health indicators and notify pharmacists of problems that need to be addressed.^[30]

5. AI-Powered Antimicrobial Management:

AMR poses a significant threat to public health. By analyzing patient data to recommend the best antibiotic therapies and reducing resistance and overuse, AI will support antimicrobial stewardship.

For example, AI can measure procalcitonin levels to help guide decisions about antibiotic therapy, making sure that antibiotics are only used when absolutely necessary. AI can also monitor antibiotic usage trends and alert doctors to misuse or overuse.^[31]

6. Ethical, Legal, and Professional Challenges:

The application of AI in clinical pharmacy raises a number of moral, legal, and professional concerns:

- Assigning blame when AI advice has unforeseen consequences is an ethical dilemma.

- Fairness and Bias: Keeping AI systems from making already-existing healthcare inequities worse.
- Data privacy: following the law to protect patient information, particularly genetic information.
- Maintaining Professional Identity: striking a balance between the pharmacist's expertise, professional judgment, and AI support Clear procedures, interdisciplinary cooperation, and ongoing education are necessary to get over such challenges.^[32,33]

Medication adherence And Patient Engagement:

Medication adherence is one of the main problems clinical pharmacists deal with since noncompliance can lead to adverse health outcomes, readmissions to the hospital, and increased medical costs.^[34] Manual follow-ups and generic reminders are examples of conventional adherence strategies that usually fail to address the individual needs of each patient. AI-powered predictive analytics is transforming drug adherence by providing more tailored, data-driven strategies. Predictive analytics uses historical data to predict patient behavior and identify potential barriers to medication adherence. By looking at factors including patient demographics, medical history, prior adherence practices, and social and economic determinants of health, AI may offer personalized adherence profiles that let doctors tailor treatments.^[35]

For instance, predictive algorithms may be able to detect people who live in places with poor access to healthcare or who have a history of missing doses. These models can also be used to identify patients who are at risk of nonadherence due to factors such as polypharmacy, complex dosage schedules, or a lack of understanding regarding their treatment plan. By incorporating real-time



data, predictive analytics can continuously update these profiles, enabling adherence tactics to be adjusted in response to changing patient circumstances. For example, predictive models can identify new issues such as financial constraints or transportation issues, or they can identify changes in a patient's health and adjust the plan accordingly. Instead of using a one-size-fits-all strategy, healthcare providers can use this dynamic, tailored intervention technique to provide patients with the greatest support available. As a result, predictive analytics greatly increases the possibility of better patient outcomes and medication compliance.^[36]

These prediction models require integration of data from various sources, including electronic health records (EHRs), pharmacological databases, and patient-reported outcomes.

This data can be collected and analyzed by artificial intelligence (AI) systems, giving doctors important information about the variables that are most likely to affect adherence for particular patients. Knowing this enables healthcare providers to take prompt action and give patients the support they require before adherence problems get worse.^[37]

Medicine adherence the extent to which a person's behavior toward medication complies with suggested norms from a healthcare professional is essential for patients with noncommunicable diseases (NCDs) in order to achieve the intended treatment outcomes. Several methods can be used to assess medication adherence. Even while objective evaluations might more reliably confirm a person's medication-taking habits, subjective measurements can help explain why a patient isn't taking their medications as directed.

Data from US Medicare members with one or more NCDs, such as diabetes, high blood pressure, and/or high cholesterol, revealed high rates of prescription non-

adherence. Of them, 76% did not take any of the three drugs, and 32% did not take more than one target pharmacological class.^[38]

AI is also changing the way pharmacists engage with patients, particularly in the area of patient counselling. Traditionally, during patient counselling, pharmacists have had one-on-one conversations with patients to address concerns, go over potential side effects, and provide instructions on how to take prescription drugs. However, budgetary and schedule limitations have frequently limited the scope of these gatherings. AI is opening the door to more customized and efficient patient care. Two AI-powered tools that give pharmacists round-the-clock access to pharmacological knowledge are chatbots and virtual assistants. These technologies can simulate a conversation with the patient by answering questions about dose, side effects, and drug interactions.

Artificial intelligence (AI) chatbots can deliver clear and consistent information to patients who might forget or misunderstand crucial aspects discussed during in-person sessions. In addition, these systems have the ability to monitor patient questions and provide recommendations for further action based on the individual requirements or concerns of the patient.^[39]

AI systems can also comprehend and interpret complicated human language thanks to natural language processing capabilities, which enables them to provide tailored counseling messages. The AI system, for example, can offer personalized recommendations, relaxing methods, and reminders to get in touch with the pharmacist if the patient continues to experience anxiety when taking a new drug. To help patients feel heard, informed, and in control of their healthcare decisions, these AI solutions can also highlight possible issues unique to a patient's medical



history and offer real-time information on drug interactions. ^[40]

By enabling a more dynamic, individualized, and interactive counseling experience, AI improves patient involvement and gives patients the power to make better medical decisions. When treating chronic illnesses, when patients must adhere to intricate regimens and take drugs on a regular basis, this involvement is especially crucial. By improving patient participation, communication, and self-management, an AI-powered patient engagement system presents a novel approach to healthcare. These technologies use cutting-edge artificial intelligence (AI) methods including machine learning, natural language processing (NLP), and predictive analytics to provide more personalized and engaging healthcare experiences. According to Taya Irizarry (2015), health information is given according to each patient's unique tastes and traits. This includes treatment plans, medication reminders, and educational materials.

Innovative healthcare solutions that improve the relationship between patients and providers are AI-powered patient engagement platforms. By using predictive modeling and data analysis, these systems provide preventative treatment and personalized health information. Patients' experiences and health results are improved by encouraging more effective and efficient patient participation. ^[41]

The use of AI-driven patient engagement in the following ways (Figure1):

1. Healthcare virtual assistants (Chatbots)
2. AI-powered patient self-service portal
3. 360-degree view of patient
4. Risk assessment for Preventive care
5. Healthcare workforce optimization

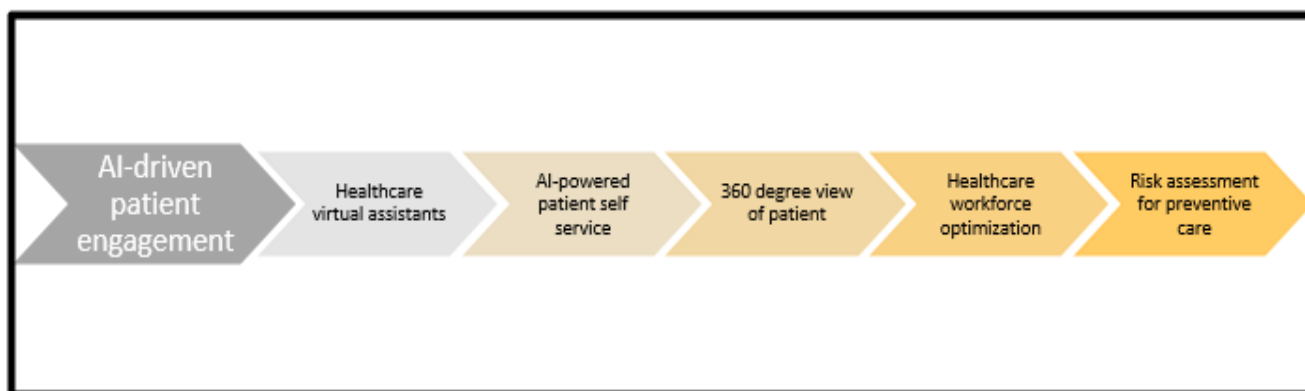


Figure 1: Patient Engagement in AI

Pharmacy operations must be accurate and efficient in order to provide safe, high-quality healthcare. It is the responsibility of pharmacies to make sure that patients follow recommended treatment plans and receive the right medications on time. But because pharmacy operations are so complicated and entail so many steps—like

ordering medications, verifying them, distributing them, and counselling patients—they frequently result in errors and inefficiencies. By causing adverse drug events, prescription errors, and a decline in patient satisfaction, these problems may jeopardize patient safety. ^[42]

By eliminating bottlenecks and simplifying processes, workflow optimization in pharmaceutical settings aims to maximize overall operational accuracy and efficiency. Numerous tactics, including process reengineering, Lean Six Sigma, and automation technology, have been researched and proposed to enhance pharmacy operations. These programs prioritize technology utilization, process standardization, and waste reduction to support pharmacists and pharmacy technicians in their work. This study aims to evaluate the impact of workflow optimization on patient safety and service quality in pharmacy operations. By examining current procedures and the effectiveness of different optimization strategies, this study aims to shed light on how pharmacies could enhance patient care and operational performance.^[43]

AI powered Clinical support system (cdss) can also give the pharmacist or healthcare provider real-time patient and case- based suggestion based on pertinent clinical provider real-time and cases suggestions based on pertinent guidelines. When a patient has smaller illness or prescription, they are crucial because manual aviation would be labours and prone to mistake. The outdated pharmaceutical system's reliance on manual processes and human comprehension may result in delays, mistake and inefficiencies.^[44]

By improving patient care, accuracy, and efficiency, artificial intelligence modern technologies are completely changing pharmacy operations. By allowing them to examine massive databases, predict trends, and complete complex activities independently, artificial intelligence (AI) may help pharmacies better meet the demands of modern healthcare. With its improvements in automated dispensing, inventory control, and decision-making support, this state-of-the-

art technology is revolutionizing the pharmaceutical sector.^[45]

Pharmacies offer a wide range of transactional services, including counseling, in addition to filling prescriptions. If AI took care of administrative duties like insurance verification, billing, and prescription verification, pharmacy staff might have more time to devote to patient care and consultation.^[46]

Clinical Case Applications: -

1. AI-assisted prostate cancer treatment:

The goal of computer science's artificial intelligence (AI) field is to create intelligent machines that can do tasks that now need human intelligence. The deep learning (DL) method to machine learning (ML) suggests that computers, like humans, may learn by imitation. Healthcare is being revolutionized by AI. In digital pathology, artificial intelligence (AI) is being used more and more to help researchers analyse bigger data sets and diagnose prostate cancer tumours more quickly and accurately. AI has demonstrated impressive accuracy in diagnosing prostate abnormalities and predicting patient outcomes, including survival and treatment response, when used in diagnostic imaging. The enormous volume of data recovered from prostate cancer genomes requires processing power that is reliable, accurate, and fast, which machine learning approaches provide. Radiation therapy can occasionally be hazardous to humans, while being an essential part of the treatment of prostate cancer. AI might be able to predict how a patient would react in the future to unfavorable side effects of treatment. Physicians may be able to more effectively plan radiation treatments with the help of these technologies. Surgical robots will be able to use information from the operating room, recognize issues, and respond properly without



requiring human input once their capabilities are extended to cover more autonomous tasks.^[47]

2. Risk Management and Patient Safety in the Artificial Intelligence Era: A Systematic Review:

Healthcare systems are complex organizations that involve human variables, technology, the physical environment, and the quality of treatment. There may be a risk to patient safety if these factors are not balanced. Hospitals use both proactive and reactive clinical risk management strategies, which are clearly required given this sickness. AI is a wonderful fit for these approaches. Examining the latest findings on the impact of AI on clinical risk management practices is the aim of this systematic review. To expedite the analysis of the review results and promote future standardized comparisons with any follow-up research, the results of the current evaluation will be grouped according to the potential application of AI in the prevention of the various incident type categories as defined by the ICPS. Materials and Methods: On November 3, 2023, a systematic review of the literature was carried out using the SCOPUS and Medline (via PubMed) databases in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A total of 297 objects were discovered. Following the screening procedure, 36 publications were included in the current systematic review. Findings and Conversation: The research reviewed in this study identified three main "incident type" categories: medicine, healthcare-associated infection, and clinical procedure. Another relevant application of AI in healthcare risk management is event reporting. Conclusions: In a range of clinical contexts, this review illustrated how AI may be applied to enhance patient safety and expedite error detection. It appears to be a promising tool to

enhance clinical risk management, despite the fact that it needs human supervision and cannot completely replace human abilities. In order to facilitate the analysis of the current review's findings and their comparison with those of subsequent systematic investigations, it was thought to be beneficial to employ a well-established taxonomy for adverse event identification. However, the results of the current study showed that, in addition to reducing risks in clinical practice, AI may be used to improve the use of event reporting, a critical risk detection tool. Therefore, the taxonomy of businesses using AI for therapeutic risk operations has to include a new class related to risk detection and analysis technologies. In this case, it was believed that the ICPS classification applied.^[48]

3. Critical Care Real-Time Drug Interaction Alerts:

A 72-year-old septic patient in the critical care unit is receiving a lot of antibiotics, sedatives, and inotropes. The EHR is continuously scanned for pharmacokinetic and pharmacodynamic interactions by an AI-powered CDSS. The method finds a high-risk interaction that causes QT prolongation between a sedative and an azole antifungal. After noting that a potentially lethal arrhythmia was avoided, the clinical pharmacist halts the order and suggests a different antifungal.^[49]

4. The Application of Antibiotics in Relation to Sepsis

Sepsis is one of the most deadly illnesses of the twenty-first century due to challenges with early and differential diagnosis. Furthermore, antibiotic resistance, or AMR, is currently the world's largest danger to human health. The only way to stop AMR from emerging and spreading is to use active pathogen identification and detection in conjunction



with resistance assessment. To improve illness management, a number of suitable diagnostic techniques must be applied for the proper administration of antibiotics and the elimination of different infectious diseases. The historical culture of suspected blood disorders serves as the foundation for the current method of sepsis detection. This approach takes longer and produces false-negative results for samples treated with antibiotics and slow-growing microorganisms. In addition to providing accurate results from those who may be sepsis victims, modern technology can test blood samples more quickly than the outdated method and provide all the information required to identify the bacteria and AMR. [50]

5. **AI-supported diabetes care**
A group of conditions known as diabetes mellitus are brought on by glucoregulatory system dysfunctions. Hyperglycaemia, the hallmark of diabetes, is the primary consequence of this imbalance. Chronic hyperglycaemia brought on by diabetes is associated with long-term issues such tissue damage and organ failure, which can reduce life expectancy and even cause death. Out of an estimated 425 million people with diabetes globally, 4 million people died from the disease in 2017, according to the International Diabetes Federation. These figures are expected to increase significantly over the next few decades, placing more and more pressure on health care systems. This is a ballpark estimate of the number of pertinent articles in the Google Scholar database. Artificial intelligence (AI) is a rapidly expanding area, and its applications in diabetes research are expanding even faster. According to the paper, advanced algorithms are typically used in data-driven approaches to facilitate in-depth

analysis and deliver personalized medical care. Additionally, there is proof that more healthcare facilities are employing these strategies. They have a good chance of succeeding in clinical practice in the near future.

The expansion of the amount of information already available and the creation of new techniques for managing and evaluating this data are the primary reasons for this rise. As a result of these advancements, tools and software have been created that can improve the efficient treatment of complex diseases like cancer and diabetes. [51]

Challenges & Ethical Consideration:

Despite its proven benefits, artificial intelligence presents a number of challenges for pharmacy. One is that some pharmacies might not have the money to pay for the early expenses of implementing AI and to hire the necessary staff.

The training and instruction required to overcome reluctance to use AI technology may make integrating AI into pharmacy operations more difficult. [52]

Another problem with ML products is limited learning even after the device has been placed on the market, which is why the FDA should keep an eye on the "total product life cycle."

The FDA's regulatory oversight approach is described in its Artificial Intelligence/Machine Learning—

Based Software as a Medical Device Action Plan. [53]

Daydreaming, a term used to describe LLM output with a strong data foundation that is challenging to distinguish from factual output, is another challenge. Healthcare professionals are concerned about accountability when it comes to lowering the

likelihood of medical negligence and determining who is accountable when a patient is harmed by an AI recommendation. As more AI applications are created, the debate over their legality will probably get more heated. [54]

Other Challenges: -

For AI systems to perform at their best, high-quality and varied datasets are necessary. AI's capacity to produce precise insights and forecasts may be constrained by the requirement for meticulous data curation and the lack of standard data formats. [55]

Since many AI modules operate as "black boxes," it could be challenging to understand how they make decision. Stakeholder trust may be damaged but this lack of transparency, hence stringent validation procedure are required to guarantee acceptability and dependability [56].

Following defined procedures is necessary for the successful integration of AI technology in health care. Healthcare professionals may become concerned and dissatisfied if clinical requirements and AI capabilities are not aligned. [57]

These days, the vast array of system designs and data formats makes it challenging to integrate AI systems with clinical trial infrastructures. This incompatibility may cause disruptions to workflow and lower productivity. [58]

Ethical consideration:

The proclamation highlights the potential benefits of artificial intelligence (AI) technologies, such as robots, machine learning, generative AI, and predictive analytics, in terms of pharmaceutical safety, efficiency, and more individualized care.

From identifying patients at high risk of non-adherence to providing real-time decision support and improving the management of chronic diseases, artificial intelligence (AI) can help chemists make better decisions that benefit patients and health systems. [59]

Galactic therapy can be guided by AI technologies, but the outcomes of the chatbot's analysis must be suitably assessed in light of a specific medical requirement. [60]

Medicine is vulnerable to similar issues since evidence-based clinical care and medications may rely on data from study populations that are biased against specific groups.

Healthcare organizations must ensure that AI models are based on sizable, high-quality data sets that incorporate extra objective measurements in order to lessen persistent biases [61]

Furthermore, generative AI might provide false or misleading data. These models should be designed to minimize the possibility of generating erroneous data by restricting the scope of possible responses. Instead of replacing the pharmaceutical sector, artificial intelligence (AI) should enhance it; human oversight is crucial when utilizing these technologies. [62]

Prepare for unforeseen outages, security breaches, or recalls just like you would with any other technology that supports pharmacy practice. For example, how are risks to patient safety recognized and addressed? ought to be supervised by institutions. In the event that the model is unavailable, what protocols should staff members adhere to in its place? Unexpected AI outcomes must be proactively identified and mitigated by an organization's AI rules and procedures.

The World Health Organization published a set of ethical standards for the application of AI in



healthcare in 2021. These considerations include the need to minimize harm and provide the highest level of objective benefit to a range of patient demographics, as well as the requirement to preserve human autonomy in AI-assisted medical decision-making and the usage of protected health information. Pharmacy executives should consider these factors while deploying AI. [63]

Future Perspective

AI will increasingly become embedded in clinical workflows, enabling pharmacists to lead in predictive care, personalized medicine, and digital health innovation. Future advancements will likely focus on equity-sensitive deployment, human-AI collaboration interfaces, and pharmacist-led governance models. As AI systems evolve to be uncertainty-aware and context-sensitive, they will support pharmacists in underserved settings, optimize therapy across diverse populations, and contribute to learning health systems that continuously improve safety and outcomes.

CONCLUSION:

Artificial intelligence is redefining the scope and impact of clinical pharmacy. By augmenting pharmacists' cognitive capabilities, AI enables more precise, proactive, and personalized interventions across the care continuum. From identifying high-risk patients and optimizing drug regimens to enhancing adherence and minimizing ADEs, AI tools are proving indispensable in modern healthcare. However, successful integration demands more than technical performance—it requires thoughtful design, ethical safeguards, and pharmacist-driven implementation.

The article underscores that AI should not replace clinical judgment but rather enhance it. Pharmacists remain essential stewards of

therapeutic safety, equity, and patient trust. As healthcare systems transition toward value-based models, AI offers a strategic advantage in achieving the triple aim: better outcomes, lower costs, and improved provider well-being. With proper governance, training, and infrastructure, clinical pharmacists are uniquely positioned to lead this digital transformation.

In essence, AI is not the future of pharmacy it is the present, rapidly unfolding. And when harnessed responsibly, it empowers pharmacists to fulfill the promise of pharmaceutical care in an era of complexity, data abundance, and rising patient expectations.

REFERENCES

1. Hepler CD, Strand LM. Opportunities and responsibilities in pharmaceutical care. *American journal of hospital pharmacy*. 1990 Mar 1;47(3):533-43.
2. Van Mil JF, Fernandez-Llimos F. What is 'pharmaceutical care' in 2013?. *International Journal of Clinical Pharmacy*. 2013 Feb;35(1):1-2.
3. American College of Clinical Pharmacy. The research agenda of the American College of Clinical Pharmacy. *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*. 2007 Feb;27(2):312-24. World Health Organization. Medication Without Harm: WHO Global Patient Safety Challenge (Report & Initiative page). 2017–2024
4. Cadogan CA, Ryan C, Hughes CM. Appropriate polypharmacy and medicine safety: when many is not too many. *Drug safety*. 2016 Feb;39(2):109-16.
5. Cho HJ, Chae J, Yoon SH, Kim DS. Aging and the prevalence of polypharmacy and hyperpolypharmacy among older adults in South Korea: a national retrospective study during



- 2010–2019. *Frontiers in pharmacology*. 2022 May 9;13:866318.
6. Cho HJ, Chae J, Yoon SH, Kim DS. Factors related to polypharmacy and hyperpolypharmacy for the elderly: a nationwide cohort study using national health insurance data in South Korea. *Clinical and translational science*. 2023 Feb;16(2):193-205.
7. Christopher C, Kc B, Shrestha S, Blebil AQ, Alex D, Mohamed Ibrahim MI, Ismail N. Medication use problems among older adults at a primary care: A narrative of literature review. *Aging Medicine*. 2022 Jun;5(2):126-37.
8. Klazinga N, Slawomirski L. The economics of patient safety: From analysis to action. *OECD Health Working Papers*. 2022 Aug 5(145):0_1-72.
9. Pao JB, Wu SC, Guo YW, Huang WH. Evaluating Pharmacist-Driven Interventions in Multidisciplinary Diabetes Care: A Quasi-Experimental Study. *The Science of Diabetes Self-Management and Care*. 2025;26350106251361368.
10. Gerstmeyer J, Avantaggio A, Gorbacheva A, Pierre C, Cracchiolo G, Patel N, Davis DD, Anderson B, Godolias P, Schildhauer TA, Abdul-Jabbar A. Incidence and predictors of readmission following hospitalization for thoracic disc herniation. *Clinical neurology and neurosurgery*. 2025 Feb 1;249:108698.
11. Tay YX, Wee JC, Ong ME, Foley SJ, Chen RC, Chan LP, Killeen R, Chua IS, McNulty JP. Optimising design of clinical decision support systems and implementation strategies to improve radiological imaging appropriateness—A qualitative study in the emergency department. *International Journal of Medical Informatics*. 2025 May 12:105966.
12. Garvelink MM, Emond J, Menear M, Brière N, Freitas A, Boland L, Perez MM, Blair L, Stacey D, Légaré F. Development of a decision guide to support the elderly in decision making about location of care: an iterative, user-centered design. *Research Involvement and Engagement*. 2016 Jul 19;2(1):26.
13. Légaré F, Brière N, Stacey D, Bourassa H, Desroches S, Dumont S, Fraser K, Freitas A, Rivest LP, Roy L. Improving Decision making On Location of Care with the frail Elderly and their caregivers (the DOLCE study): study protocol for a cluster randomized controlled trial. *Trials*. 2015 Feb 12;16(1):50.
14. Murphy RM, Klopotoska JE, de Keizer NF, Jager KJ, Leopold JH, Dongelmans DA, Abu-Hanna A, Schut MC. Adverse drug event detection using natural language processing: A scoping review of supervised learning methods. *Plos one*. 2023 Jan 3;18(1):e0279842.
15. Golder S, O'Connor K, Lopez-Garcia G, Tatonetti N, Gonzalez-Hernandez G. Leveraging Unstructured Data in Electronic Health Records to Detect Adverse Events from Pediatric Drug Use-A Scoping Review. *medRxiv*. 2025 Mar 20.
16. Rammal DS, Alomar M, Palaian S. AI-Driven pharmacy practice: Unleashing the revolutionary potential in medication management, pharmacy workflow, and patient care. *Pharmacy Practice*. 2024 May 31;22(2):1-1.
17. Lester C, Rowell B, Zheng Y, Marshall V, Kim JY, Chen Q, Kontar R, Yang XJ. Effect of Uncertainty-Aware AI Models on Pharmacists' Reaction Time and Decision-Making in a Web-Based Mock Medication Verification Task: Randomized Controlled Trial. *JMIR Medical Informatics*. 2025 Apr 18;13(1):e64902.
18. Kim JY, Marshall VD, Rowell B, Chen Q, Zheng Y, Lee JD, Kontar RA, Lester C, Yang XJ. The effects of presenting AI uncertainty information on pharmacists' trust in automated



- pill recognition technology: exploratory mixed subjects study. *JMIR Human Factors*. 2025 Feb 11;12:e60273.
19. Murphy RM, Klopotoska JE, de Keizer NF, Jager KJ, Leopold JH, Dongelmans DA, Abu-Hanna A, Schut MC. Adverse drug event detection using natural language processing: A scoping review of supervised learning methods. *Plos one*. 2023 Jan 3;18(1):e0279842.
20. Rammal DS, Alomar M, Palaian S. AI-Driven pharmacy practice: Unleashing the revolutionary potential in medication management, pharmacy workflow, and patient care. *Pharmacy Practice*. 2024 May 31;22(2):1-1.
21. Kandhare P, Kurlekar M, Deshpande T, Pawar A. Artificial Intelligence in Pharmaceutical Sciences: A Comprehensive Review. *Medicine in Novel Technology and Devices*. 2025 Jun 13:100375.
22. Ogbuagu OO, Mbata AO, Balogun OD, Oladapo O, Ojo OO, Muonde M. Artificial intelligence in clinical pharmacy: Enhancing drug safety, adherence, and patient-centered care. *International Journal of Multidisciplinary Research and Growth Evaluation*. 2023 Jan;4(1):814-22.
23. Lester C, Rowell B, Zheng Y, Marshall V, Kim JY, Chen Q, Kontar R, Yang XJ. Effect of Uncertainty-Aware AI Models on Pharmacists' Reaction Time and Decision-Making in a Web-Based Mock Medication Verification Task: Randomized Controlled Trial. *JMIR Medical Informatics*. 2025 Apr 18;13(1):e64902.
24. Topol E. *Deep medicine: how artificial intelligence can make healthcare human again*. Hachette UK; 2019 Mar 12.
25. Sendak MP, D'Arcy J, Kashyap S, Gao M, Nichols M, Corey K, Ratliff W, Balu S. A path for translation of machine learning products into healthcare delivery. *EMJ Innov*. 2020 Jan 27;10:19-00172.
26. Collins FS, Varmus H. A new initiative on precision medicine. *New England journal of medicine*. 2015 Feb 26;372(9):793-5.
27. Wang F, Casalino LP, Khullar D. Deep learning in medicine—promise, progress, and challenges. *JAMA internal medicine*. 2019 Mar 1;179(3):293-4.
28. Nieuwlaat R, Wilczynski N, Navarro T, Hobson N, Jeffery R, Keenanasseril A, Agoritsas T, Mistry N, Iorio A, Jack S, Sivaramalingam B. Interventions for enhancing medication adherence. *Cochrane database of systematic reviews*. 2014(11).
29. Jiang F, Jiang Y, Zhi H, Dong Y, Li H, Ma S, Wang Y, Dong Q, Shen H, Wang Y. Artificial intelligence in healthcare: past, present and future. *Stroke and vascular neurology*. 2017 Dec 1;2(4).
30. Dat TV, Tu VL, Quan NK, Minh NH, Trung TD, Le TN, Phuc-Vinh D, Trinh DT, Pham Dinh L, Nguyen-Thi HY, Huy NT. Telepharmacy: a systematic review of field application, benefits, limitations, and applicability during the COVID-19 pandemic. *Telemedicine and e-Health*. 2023 Feb 1;29(2):209-21.
31. Elshenawy RA, Umaru N, Alharbi AB, Aslanpour Z. Antimicrobial stewardship implementation before and during the COVID-19 pandemic in the acute care settings: a systematic review. *BMC Public Health*. 2023 Feb 10;23(1):309.
32. Hasan HE, Jaber D, Khabour OF, Alzoubi KH. Ethical considerations and concerns in the implementation of AI in pharmacy practice: a cross-sectional study. *BMC Medical Ethics*. 2024 May 16;25(1):55.
33. Char DS, Shah NH, Magnus D. Implementing machine learning in health care—addressing

- ethical challenges. *The New England journal of medicine*. 2018 Mar 15;378(11):981.
34. Razzak MI, Imran M, Xu G. Big data analytics for preventive medicine. *Neural Computing and Applications*. 2020 May;32(9):4417-51.
35. Mehta N, Pandit A, Shukla S. Transforming healthcare with big data analytics and artificial intelligence: A systematic mapping study. *Journal of biomedical informatics*. 2019 Dec 1;100:103311.
36. Eichler HG, Bloechl - Daum B, Broich K, Kyrle PA, Oderkirk J, Rasi G, Santos Ivo R, Schuurman A, Senderovitz T, Slawomirski L, Wenzl M. Data rich, information poor: can we use electronic health records to create a learning healthcare system for pharmaceuticals?. *Clinical Pharmacology & Therapeutics*. 2019 Apr;105(4):912-22.
37. Lam WY, Fresco P. Medication adherence measures: an overview. *BioMed research international*. 2015;2015(1):217047.
38. Leslie RS, Tirado B, Patel BV, Rein PJ. Evaluation of an integrated adherence program aimed to increase Medicare Part D star rating measures. *Journal of Managed Care Pharmacy*. 2014 Dec;20(12):1193-203.
39. Khan O, Parvez M, Kumari P, Parvez S, Ahmad S. The future of pharmacy: how AI is revolutionizing the industry. *Intelligent Pharmacy*. 2023 Jun 1;1(1):32-40.
40. Khan O, Parvez M, Kumari P, Parvez S, Ahmad S. *Intelligent Pharmacy*. nutrition.;17:18.
41. Singh G, Kaur R, Gupta J, Devi N, Thakur S. Revolutionizing Pharmacy with Artificial Intelligence: Applications and Challenges.
42. Bachina L, Kanagala A. Health revolution: AI-powered patient engagement. *International Journal of Chemical and Biochemical Sciences*. 2023;24(5):2023.
43. Coulter A, Ellins J. Effectiveness of strategies for informing, educating, and involving patients. *Bmj*. 2007 Jul 5;335(7609):24-7.
44. Richards T. Partnership with patients: Patients want more than simply information; they need involvement too. *Bmj*. 1998 Jan 10;316(7125):85-6.
45. Allam H. Prescribing the future: The role of artificial intelligence in pharmacy. *Information*. 2025 Feb 11;16(2):131.
46. Barua R, Das D, Biswas N. Revolutionizing drug discovery with artificial intelligence: enhancing efficiency, addressing ethical concerns, and overcoming limitations. In *Approaches to human-centered AI in healthcare 2024* (pp. 62-85). IGI Global Scientific Publishing.
47. Tătaru OS, Vartolomei MD, Rassweiler JJ, Virgil O, Lucarelli G, Porpiglia F, Amparore D, Manfredi M, Carrieri G, Falagario U, Terracciano D. Artificial intelligence and machine learning in prostate cancer patient management—current trends and future perspectives. *Diagnostics*. 2021 Feb 20;11(2):354.
48. Ferrara M, Bertozzi G, Di Fazio N, Aquila I, Di Fazio A, Maiese A, Volonnino G, Frati P, La Russa R. Risk management and patient safety in the artificial intelligence era: a systematic review. In *Healthcare 2024* Feb 27 (Vol. 12, No. 5, p. 549). MDPI.
49. Kumar P, Zhao M, Chan T. Development of an AI-based real-time drug-drug interaction alert system in ICU settings. *Journal of Critical Care Medicine*. 2023;51(3):210–218.
50. Gupta E, Saxena J, Kumar S, Sharma U, Rastogi S, Srivastava VK, Kaushik S, Jyoti A. Fast track diagnostic tools for clinical management of sepsis: paradigm shift from conventional to advanced methods. *Diagnostics*. 2023 Jan 11;13(2):277.

51. Contreras I, Vehi J. Artificial intelligence for diabetes management and decision support: literature review. *Journal of medical Internet research*. 2018 May 30;20(5):e10775.
52. Belagodu Sridhar S, Karattuthodi MS, Parakkal SA. Role of artificial intelligence in clinical and hospital pharmacy. In *Application of Artificial Intelligence in Neurological Disorders* 2024 Jul 1 (pp. 229-259). Singapore: Springer Nature Singapore.
53. Alanazi RJ. Role of artificial intelligence in pharmacy practice: A systematic review. *Archives of Pharmacy Practice*. 2024;15(2-2024):34-42.
54. Wong A, Flanagan T, Covington EW, Nguyen E, Linn D, Brummel G, Hoffmaster B, Isaacs D, Kane - Gill SL. Forecasting the impact of artificial intelligence on clinical pharmacy practice. *Journal of the American College of Clinical Pharmacy*. 2025 Apr;8(4):302-10.
55. Gupta D, Wal P, Wal A, KR S, Kumar M, Panda KC, Sharma MC. AI in clinical trials and drug development: challenges and potential and advancements. *Current Drug Discovery Technologies*. 2024 Oct 28.
56. Li Y, Cui X, Yang X, Liu G, Zhang J. Artificial intelligence in predicting pathogenic microorganisms' antimicrobial resistance: challenges, progress, and prospects. *Frontiers in Cellular and Infection Microbiology*. 2024 Nov 1;14:1482186.
57. Owoyemi A, Okpara E, Okor M, Awais F, Harwani S, Salwei M, Boyd A. Lessons for Approaching Implementation of AI Systems in Clinical Settings. In *2024 IEEE 12th International Conference on Healthcare Informatics (ICHI) 2024 Jun 3 (pp. 472-477)*. IEEE.
58. Mohammed S. The impact of AI on clinical trial management. *Int. J. Adv. Res. Comput. Commun. Eng*. 2024 Jun;13(3).
59. "FIP VIRTUAL 2020: Pharmaceutical Practice: Academic Pharmacy". *Pharmacy Education*, vol. 20, no. 3, Sept. 2020, pp. p 1 - 12.
60. Dastani M, Mohseni M. Artificial intelligence chatbots in medical education: a literature review of potential benefits and challenges. *International Journal of Medical Reviews*. 2024 Jun 1;11(2):710-5.
61. Parikh RB, Teeple S, Navathe AS. Addressing bias in artificial intelligence in health care. *Jama*. 2019 Dec 24;322(24):2377-8.
62. Yaraghi N. Generative AI In health care: opportunities, challenges, and policy. *Health Affairs Forefront*. 2024.
63. Samantha Bastow, Craig Greszler, Elizabeth Hartell, Asha Kalichira, Shawn Mathew, Derek Rhodes, Sonya Zhan, Scott V Anderson, ASHP Statement on Artificial Intelligence in Pharmacy, *American Journal of Health-System Pharmacy*, 2025; zxaf107.

HOW TO CITE: Darshana Sunil Nagmoti, Khode Aniket Prakash*, Netra Nitin Marathe, Harsh Santosh Jadhav, Tanuja Wankhede, Beyond Dispensing: AI Empowering Clinical Pharmacist, *Int. J. of Pharm. Sci.*, 2025, Vol 3, Issue 10, 1064-1080
<https://doi.org/10.5281/zenodo.17336807>

