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## Review Article

# Artificial Intelligence in Hospital Pharmacy and Current Application, Challenges, and Future Perspectives.

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## ABSTRACT

Artificial Intelligence (AI) is emerging as an important technology in modern healthcare and is gradually changing the way hospital pharmacy services are delivered. In hospital pharmacy practice, AI can support pharmacists in activities such as prescription screening, medication error detection, drug interaction checking, adverse drug reaction monitoring, inventory management, antimicrobial stewardship, drug information services, and personalized patient care. By processing large amounts of clinical and pharmaceutical data, AI-based systems can help identify potential medication-related problems more quickly and support pharmacists in making informed decisions. AI can also improve the efficiency of drug procurement, stock forecasting, dispensing, and medication-use processes, thereby reducing workload and improving patient safety. However, the implementation of AI also presents challenges, including data privacy and security, inaccurate or biased outputs, limited transparency of algorithms, integration with existing hospital systems, financial costs, and the need for trained healthcare professionals. Therefore, AI should be considered a supportive technology rather than a replacement for pharmacists. Effective collaboration between AI systems and pharmacy professionals, along with appropriate ethical, legal, and regulatory frameworks, will be essential for its safe and responsible use. This review discusses the current applications, benefits, challenges, ethical and legal considerations, and future potential of AI in hospital pharmacy practice.

## INTRODUCTION

Artificial intelligence (AI) is increasingly becoming an important tool in hospital pharmacy, assisting

pharmacists in various clinical and operational activities, including medication selection, dosage optimization, identification of potential drug interactions, inventory control, and patient counselling. The

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increasing complexity of pharmacotherapy and the continuous growth of healthcare-related data have created a need for advanced, efficient, and data-driven approaches to pharmaceutical care. AI-based systems, particularly machine learning (ML), can process and interpret large healthcare datasets to identify medication-related problems, support clinical decision-making, and improve the safety and quality of drug therapy.

Major applications of AI in hospital pharmacy include automated drug dispensing, clinical decision-support systems, medication reconciliation, detection of adverse drug reactions, medication-demand prediction, inventory management, and individualized pharmacotherapy. By integrating these technologies into pharmacy practice, healthcare institutions can improve medication safety, streamline workflow, optimize the utilization of resources, and reduce the burden of repetitive tasks on pharmacists, ultimately contributing to better patient care and clinical outcomes.

This review provides an overview of the existing applications of AI in hospital pharmacy, along with its potential benefits, limitations, recent technological developments, emerging innovations, and future prospects. It emphasizes the potential of AI to support safer, more efficient, evidence-based, data-driven, and patient-centered pharmaceutical care while enhancing the evolving role of pharmacists within modern healthcare systems [1].

### **History of AI in Pharmacy and Hospital Pharmacy**

Artificial intelligence has become an increasingly important part of pharmacy and hospital services. Although its use is relatively new, AI now supports medication management, clinical decision-making, and more efficient patient care.

#### **1. Early Development: 1950s–1970s**

AI emerged as a field during the 1950s, influenced by pioneers such as Alan Turing and John McCarthy. Early computers enabled basic automation, though healthcare and pharmacy were not yet major areas of application.

By the late 1960s and early 1970s, AI began to be explored in medicine through expert systems. One example was MYCIN, developed at Stanford University in

the 1970s. It helped identify infectious diseases and suggest possible treatments using patient information. In pharmacy, early automated drug-dispensing machines also appeared, but AI-based pharmacy practice was still very limited.

#### **2. Automation and Clinical Support: 1980s–1990s**

During the 1980s, hospitals began using clinical decision-support systems. These tools assisted healthcare workers by providing guidance on medication therapy, drug interactions, and appropriate doses, often using rules developed by clinical experts.

In the 1990s, hospitals introduced robotic dispensing systems to make medication distribution more accurate and efficient. These technologies helped reduce mistakes in preparing and supplying medicines. Barcode systems also improved safety by supporting better medication tracking and administration. At the same time, electronic health records and larger drug-information databases created a stronger foundation for advanced AI tools.

#### **3. Expansion of AI in Healthcare: 2000s–2010s**

In the 2000s, machine learning and large-scale health-data analysis became more common in healthcare. AI systems were used to estimate patient risks, predict outcomes, identify high-risk individuals, and support the selection of suitable drug therapies. These systems drew information from medical records, clinical research, and drug databases.

By the 2010s, AI increasingly supported personalized medicine. Algorithms could examine genetic details, health records, and prior treatments to recommend more individualized care. AI-enabled clinical support tools also helped pharmacists manage complicated medication plans and choose appropriate therapies. In addition, robotic process automation began assisting with routine pharmacy work, including inventory management, medication purchasing, and prescription processing [1].

### **Evolution of Hospital Pharmacy**

The role of pharmacy has changed considerably from its traditional focus on dispensing medicines. Earlier, pharmacists were mainly involved in activities such as



counting medicines, labeling containers, pricing, maintaining stock, and supplying pharmaceutical products. Although these functions were essential, they did not fully utilize the pharmacist's professional knowledge and clinical skills. With the development of modern healthcare, pharmacists gradually began to take on broader responsibilities as clinical pharmacists and drug information providers. This transition required improvements in pharmacy education, professional training, and working practices.

The growth of medicine, surgery, hospital services, and pharmaceutical technology created a need for pharmacists to contribute more actively to patient care. Hospital pharmacy therefore evolved from a product-oriented

service into a patient-centered and clinically focused profession. Modern hospital pharmacists participate in medication selection and management, drug information services, patient counselling, monitoring of therapy, prevention of medication-related problems, and promotion of safe and rational medicine use. This evolution has established the pharmacist as an important member of the multidisciplinary healthcare team and has strengthened the role of hospital pharmacy in improving patient safety and treatment outcomes [20].

## 2.AI TECHNOLOGY RELEVANT TO HOSPITAL

| TECHNOLOGY                      | CORE FUNCTION                          | HOSPITAL PHARMACY EXAMPLES                                | MAIN FUNCTION                      |
|---------------------------------|----------------------------------------|-----------------------------------------------------------|------------------------------------|
| Expert system                   | Rule - base reasoning                  | Contraindication checks; formulary rules                  | Rigid rules; maintenance burden    |
| Rigid rules; maintenance burden | Learns patterns from data              | ADE risk: demand forecasting; prescription screening      | Bias; generalizability             |
| Deep learning                   | Complex nonlinear pat learning         | Text, imaging, high dimensional prediction                | Interpretability; data needs       |
| NLP                             | Processes clinical language            | ADR extraction; discharge summaries; medication histories | Ambiguity; context errors          |
| Knowledge graphs                | Connect entities/ relationships        | Drug-drug-disease relationship mapping                    | Construction and maintenance       |
| Computer vision                 | Analyzes images/video                  | Barcode verification; pill/ image recognition             | Image quality; edge classes        |
| LLMS                            | Language generation/ reasoning support | Drafting notes; information retrieval; patient education  | Hallucination; privacy; validation |

**Deterministic rules (Expert systems):** Useful for clear hospital policies like maximum medication doses, formulary restrictions, and allergy checks.

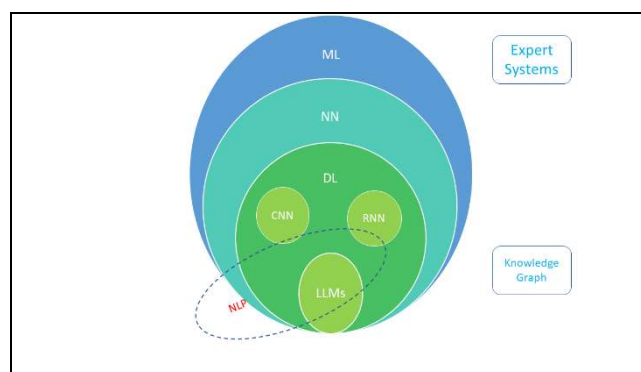
**Machine Learning (ML) models:** Best for probabilistic tasks such as assessing a patient's risk of adverse events.

**Natural Language Processing (NLP):** Valuable for extracting clinically important data from free-text documents like progress notes, discharge summaries, and adverse-event reports.

**Large Language Models (LLMs):** Offer advanced capabilities to summarize, classify, retrieve, and generate natural-language content. WHO highlights their potential in healthcare, research, public health, and drug

development, while stressing the importance of governance and human oversight.

**In hospital pharmacy:** LLMs could assist by summarizing medication histories or translating clinical data into patient-friendly explanations. However, all outputs must be verified before being used in patient care .



## AI TECHNOLOGY RELEVANT TO HOSPITAL

### 3. APPLICATIONS

#### (3.1) personalized medicine

Personalized medicine is an important approach in modern healthcare that focuses on providing diagnosis and treatment according to the individual characteristics of each patient. Traditionally, many medical decisions have been based on findings obtained from large patient populations. However, advances in genomic and molecular technologies have made it possible to consider individual genetic and biological differences while selecting appropriate therapeutic strategies. This has contributed to the development of precision medicine, where treatment decisions are increasingly guided by patient-specific information.

The concept of personalized medicine is not limited to genetic information alone. A patient's health and response to treatment can also be influenced by several other factors, including physiological and biochemical parameters, age and demographic characteristics, lifestyle, psychological status, environmental conditions, and social factors. Information obtained from clinical investigations, medical imaging, genomic and other omics-based tests, wearable devices, mobile applications, and Internet of Things (IoT)-enabled devices can therefore provide a more comprehensive picture of an individual's health status.

Artificial intelligence (AI) can support personalized medicine by bringing together these different types of patient information and analyzing them in an integrated manner. AI-based systems can help identify patterns within complex datasets and may assist healthcare professionals in understanding differences in patients' responses to medicines and treatment approaches. In hospital pharmacy practice, such capabilities may support more individualized medication-related decisions, particularly when patient-specific clinical and biological information needs to be considered.

Despite these potential benefits, the extensive use of personal health information also creates important concerns related to data privacy, security, ownership, and responsible data handling. Therefore, the effective application of AI in personalized medicine requires not only reliable analytical technologies but also

appropriate measures to protect sensitive patient information. A balanced approach combining technological development with ethical and privacy safeguards is essential for the responsible use of personalized healthcare [2,18].

#### (3.2) Clinical Decision Support Systems (CDSS) in Hospital Pharmacy

Clinical Decision Support Systems (CDSS) are increasingly being integrated into hospital pharmacy practice to assist pharmacists and other healthcare professionals in making safe and evidence-based decisions. When combined with Artificial Intelligence (AI), these systems can process large amounts of patient and medication-related information and provide clinically relevant recommendations. AI-enabled CDSS can support prescription evaluation, drug–drug interaction screening, medication selection, dose optimization, and identification of patients who may be at risk of adverse drug reactions (ADRs).

One important application of CDSS is the assessment of drug–drug interactions (DDIs). Conventional alert systems may generate a large number of notifications, including interactions that have limited clinical significance. Excessive alerts can contribute to alert fatigue, making it difficult for pharmacists to identify clinically important warnings. AI-based CDSS can analyze the severity of an interaction together with patient-specific information such as current medications, medical history, laboratory findings, and existing diseases. This allows potentially serious interactions to be prioritized and presented to the pharmacist for appropriate clinical review.

CDSS can also assist in medication appropriateness assessment. AI algorithms can evaluate a prescribed medicine in relation to individual patient characteristics, including age, renal function, hepatic function, comorbidities, and other relevant clinical parameters. For example, in a patient with impaired renal function, the system may identify a medicine or dosage that requires modification. Such support can help pharmacists recognize potential medication-related problems before they result in adverse outcomes.

Another significant application is the prediction and prevention of adverse drug reactions. Machine learning



models can analyze information from electronic health records (EHRs), previous treatment histories, demographic characteristics, laboratory data, and other clinical variables to identify patterns associated with increased ADR risk. Patients with a previous history of drug allergy or other risk factors can therefore be identified earlier, allowing pharmacists and clinicians to consider suitable alternatives or enhanced monitoring.

Overall, AI-supported CDSS can strengthen the role of pharmacists in clinical decision-making by providing timely, patient-specific information. It may improve medication safety, reduce preventable errors, support efficient clinical workflows, and contribute to more individualized pharmaceutical care. However, these systems should function as decision-support tools rather than replacements for professional judgment. Their effectiveness also depends on the quality of clinical data, appropriate integration with hospital information systems, and adequate training of pharmacy professionals [1,11].

### **(3.3) AI for automated medication dispensing system**

Artificial intelligence (AI) is increasingly being integrated into automated medication dispensing systems to improve the accuracy, safety, and efficiency of medication distribution in hospitals. AI-enabled dispensing cabinets can monitor available medicines, verify prescription information, and support accurate dispensing, thereby reducing the possibility of human errors. These systems are particularly useful in busy hospital pharmacies, where large numbers of prescriptions need to be processed within a limited time. By automating routine dispensing activities, pharmacists can devote more time to clinical responsibilities and patient care.

AI also contributes to smart inventory management by analyzing medication-use patterns and predicting future drug requirements. Based on these predictions, the system can assist in timely stock replenishment and maintain appropriate inventory levels. This helps prevent medicine shortages, avoid unnecessary overstocking, and minimize wastage caused by expired products.

Another important application is the use of robotic dispensing systems in inpatient hospital pharmacies. These systems can automate the preparation, counting,

packaging, and distribution of unit-dose medications. Automation allows medicines to be processed rapidly and consistently, particularly in high-volume settings, while reducing dependence on repetitive manual operations. Overall, the integration of AI with automated and robotic dispensing technologies can strengthen medication safety, improve pharmacy workflow, and support more efficient hospital medication-management practices [3,7].

### **(3.4) AI Technologies and Their Deployment in Hospital Pharmacy Practice**

The use of artificial intelligence (AI) in hospital pharmacy is developing from conventional rule-based decision systems toward advanced data-driven and language-based technologies. Different AI approaches, including expert systems, machine learning (ML), deep learning (DL), natural language processing (NLP), and large language models (LLMs), can support different aspects of pharmaceutical practice. The appropriate technology should therefore be selected according to the clinical or administrative requirement, availability of reliable data, expected performance, and feasibility of implementation rather than simply adopting the newest AI technology.

Expert systems are particularly useful when pharmacy activities can be clearly defined through established rules and guidelines. They can support applications such as prescription checking, regulatory compliance assessment, and basic drug–drug interaction screening. Their major advantage is transparency because the reasoning process can generally be traced to predefined rules. However, their usefulness may be restricted when clinical situations are complex, uncertain, or difficult to represent using fixed rules.

Machine learning provides a data-driven approach in which algorithms identify patterns from previously collected healthcare and pharmacy data. In hospital pharmacy, ML can assist with adverse drug reaction prediction, individualized dose estimation, therapeutic drug monitoring, drug-demand forecasting, and inventory management. These applications can support pharmacists in making more consistent and evidence-based decisions. However, the performance of ML systems



depends considerably on the quality, quantity, and representativeness of the training data.

Deep learning extends these capabilities by using multilayer neural networks to identify complex patterns, particularly in large and unstructured datasets. It can be applied to medical images, clinical text, sequential patient information, and other complex pharmacy-related datasets. In hospital pharmacy, DL may contribute to medication identification, risk prediction, pharmacogenomic analysis, and other advanced clinical applications. Nevertheless, its relatively high computational requirements and limited interpretability can create challenges when it is used for high-stakes clinical decisions.

Large language models represent a newer development in AI and are capable of processing and generating human-like text. In hospital pharmacy practice, LLMs may assist with patient medication queries, preparation of medication-related information, prescription review, clinical documentation, and pharmacovigilance reporting. Their ability to interact using natural language may improve communication between pharmacists, healthcare professionals, and patients. However, generated information must be critically evaluated because LLMs may produce inaccurate or unsupported responses.

NLP also has an important role in hospital pharmacy because much clinically relevant information is stored as unstructured text. NLP techniques can extract medication names, doses, allergy information, adverse drug reactions, and other relevant information from electronic health records, prescriptions, clinical notes, and pharmacovigilance reports. This information can subsequently be converted into structured data for use in clinical decision-support and medication-management systems.

In practice, these AI technologies do not need to function independently. A hospital pharmacy system may combine several approaches to create an integrated workflow. For example, an LLM could support patient communication, an expert system could perform rule-based medication safety checks, and a deep learning model could assist with individualized risk assessment. Such integration may allow AI to support different stages of pharmaceutical care, from prescription

assessment and medication dispensing to monitoring and follow-up.

Thus, successful deployment of AI in hospital pharmacy should be based on a clear clinical or operational need, appropriate technology selection, reliable data, pharmacist oversight, and continuous evaluation. AI should function as a supportive tool that enhances pharmacists' efficiency and decision-making rather than replacing professional judgment [4].

### **(3.5) AI for Predicting Medication Adherence**

Medication adherence is an important factor in achieving the desired therapeutic outcome. However, some patients may not take their medicines regularly because of factors such as complex treatment schedules, forgetfulness, socioeconomic difficulties, limited understanding of therapy, or individual behavioral patterns. Artificial intelligence (AI) can provide a useful approach for identifying patients who are more likely to experience medication-adherence problems.

AI-based systems can analyze large amounts of patient information, including medication history, clinical records, behavioral patterns, and relevant socioeconomic characteristics. By identifying relationships within these data, machine-learning algorithms can estimate the likelihood that a patient may have difficulty following the prescribed treatment. This predictive approach allows healthcare professionals, particularly pharmacists, to recognize potential adherence problems at an earlier stage rather than waiting until treatment failure or missed doses become evident.

Another important application of AI is the development of personalized adherence-support strategies. Patients may differ considerably in their communication preferences, understanding of medicines, daily routines, and reasons for missing doses. AI systems can help classify patients according to these characteristics and provide information that is more appropriate to their individual needs. For example, a patient who frequently forgets doses may benefit from personalized medication reminders, whereas another patient may require additional counselling or educational information about the importance of continuing treatment.

In hospital pharmacy practice, such predictive information can assist pharmacists in planning targeted



interventions. Instead of providing the same adherence strategy to every patient, pharmacists can use AI-generated risk information to focus their counselling and follow-up efforts on patients who may require greater support. Personalized reminders, educational materials, follow-up communication, and focused counselling can therefore be incorporated into medication-management services.

AI can also contribute to continuous monitoring of medication-use patterns. When new patient information becomes available, predictive models may help identify changes that indicate an increased risk of poor adherence. This creates an opportunity for earlier intervention and more patient pharmaceutical care. However, AI should function as a supportive tool rather than replacing the professional judgement of pharmacists. Patient privacy, data security, accuracy of predictions, and appropriate clinical oversight are important considerations when implementing such systems.

Overall, AI-based prediction of medication adherence represents a promising application of intelligent technology in hospital pharmacy. By identifying patients at higher risk of non-adherence and supporting personalized interventions, AI can help pharmacists provide more targeted medication counselling and follow-up. Its effective implementation may contribute to better medication use, improved treatment continuity, and potentially improved patient outcomes [3].

### **(3.6) pharmacovigilance and drug safety**

Pharmacovigilance is an essential component of healthcare that focuses on the identification, assessment, prevention, and monitoring of adverse drug reactions and other medication-related safety problems. With the increasing availability of electronic health records, clinical databases, patient-generated information, and other digital health data, artificial intelligence (AI) has emerged as a valuable tool for strengthening drug safety surveillance. AI-based approaches can process large and complex datasets more rapidly than conventional manual methods, helping pharmacists and other healthcare professionals recognize possible safety concerns at an earlier stage.

#### **1. AI-Assisted Adverse Event Detection and Reporting-**

AI can support the detection of suspected adverse drug reactions (ADRs) by examining information obtained from electronic health records, adverse-event reporting systems, clinical documentation, patient-generated content, and other healthcare data sources. Machine learning and natural language processing techniques can identify relationships between particular medicines and reported symptoms or adverse events, even when the relevant information is present in unstructured clinical text.

Automated analysis can help identify recurring patterns associated with a particular drug or patient group. When a potentially important safety event is detected, AI-based systems can generate alerts for further assessment by pharmacists or other healthcare professionals. This may help reduce delays in recognizing adverse reactions and support more consistent reporting to appropriate pharmacovigilance systems.

Another potential advantage is improved organization of safety information. Manual reporting may be affected by incomplete documentation, inconsistent terminology, or under-reporting. AI tools can assist in extracting relevant information and organizing it into a structured format, thereby supporting more systematic pharmacovigilance activities. However, AI-generated signals should be reviewed by qualified professionals before regulatory or clinical decisions are made[17].

#### **2. Safety Signal Detection Using Real-World Data-**

A major application of AI in pharmacovigilance is the identification of emerging safety signals from real-world evidence. Machine learning algorithms can evaluate large datasets obtained from sources such as electronic medical records, pharmacy records, post-marketing surveillance databases, clinical studies, and patient-generated health information. By examining relationships and trends within these datasets, AI may identify unusual patterns that could indicate a previously unrecognized drug-related safety concern. For example, an unexpected increase in a particular adverse event among patients receiving a specific medication may be highlighted for further investigation. This allows pharmacovigilance teams to focus their attention on potentially important signals rather than reviewing every record manually.



AI-based analysis can also support continuous monitoring of drug safety. As new information becomes available, predictive models can be updated to identify changing patterns and possible risk factors. Nevertheless, an identified signal does not necessarily establish a causal relationship between a drug and an adverse event. Clinical and epidemiological evaluation remains necessary to confirm the significance of the finding.

### 3. Continuous Monitoring of High-Risk Medicines-

Certain medicines require particularly careful monitoring because inappropriate use or dosing can result in serious harm. Examples include anticoagulants, opioids, and immunosuppressive medicines. AI can assist hospital pharmacy teams by continuously analyzing prescribing, dispensing, and patient-monitoring information associated with these drugs.

Machine learning systems may identify unusual prescribing patterns, excessive doses, potentially risky drug combinations, or other deviations from expected medication-use patterns. For example, abnormal prescribing or utilization trends involving controlled medicines may be flagged for pharmacist review. Similarly, patient-monitoring information can be analyzed to identify warning signs associated with treatment-related complications.

For anticoagulant therapy, AI-supported systems may help identify patients who require closer monitoring by analyzing medication records and relevant clinical information. In the case of other high-risk medicines, AI can assist in recognizing potentially unsafe patterns at an early stage. These applications can strengthen routine surveillance while allowing pharmacists to concentrate on cases that require professional assessment.

### 4. Role of AI in Improving Drug Safety-

The integration of AI into pharmacovigilance can support several important activities within hospital pharmacy practice. It can assist in the early recognition of adverse events, facilitate the analysis of large volumes of safety data, identify potential safety signals, and support continuous monitoring of high-risk medicines. These capabilities may improve the efficiency of pharmacovigilance activities and provide pharmacists with additional information for clinical review.

Despite these advantages, AI should function as a decision-support tool rather than a complete replacement for professional judgment. The reliability of AI-based pharmacovigilance depends on the quality, completeness, and representativeness of the available data. Issues related to patient privacy, data security, algorithmic reliability, false-positive signals, and integration with existing healthcare systems must also be considered.

Overall, AI has the potential to strengthen pharmacovigilance by making drug safety monitoring more data-driven, timely, and systematic. When combined with pharmacist expertise and appropriate clinical and regulatory oversight, AI-based surveillance can contribute to the early recognition and management of medication-related risks and support safer use of medicines [1,6,8].

#### (3.7) Dose Recommendation

AI-based dose recommendation systems can assist healthcare professionals in selecting an appropriate drug dose for individual patients. A dose recommendation may include a specific dose, such as a value expressed in milligrams, or a change in the dosing interval, such as extending the time between two doses. In some situations, the system may indicate that no dose adjustment is necessary or suggest avoiding a particular medicine and selecting an alternative drug.

The recommendation should be specific and clinically meaningful rather than based on general statements such as “use with caution” or “start with the lowest possible dose.” When adequate information is available, factors such as the patient's clinical condition and liver function may be considered while determining the appropriate dose. For patients with different levels of hepatic impairment, separate dose recommendations may be required.

If sufficient evidence is not available to determine a suitable starting dose, a general recommendation for therapeutic drug monitoring alone may not be considered a specific dose recommendation. Therefore, AI-assisted dose recommendations should provide clear, patient-specific guidance that can support pharmacists and other healthcare professionals in making safe medication decisions [12,17].



### **(3.8) Patient-Specific Drug Therapy**

Patient-specific drug therapy is an important component of personalized medicine because it focuses on selecting and optimizing treatment according to the individual characteristics of each patient. The main objective is to improve therapeutic effectiveness while minimizing adverse effects and achieving better overall treatment outcomes. Unlike a one-size-fits-all approach, patient-specific therapy considers the biological characteristics of the patient and the way these characteristics may influence the response to a particular medicine.

Protein-based medicines have gained considerable importance in personalized therapy because of their high target specificity and biological activity. These drugs can act on specific biological targets involved in disease processes and therefore may provide more targeted treatment. Patient-related protein information can be used during the development and selection of therapies designed to act on particular molecular targets.

Advances in technologies such as mass spectrometry and two-dimensional gel electrophoresis have also improved the understanding of protein variations in the human body. A single protein may exist in different forms, known as isoforms, and these variations can influence how a patient responds to a drug. As a result, differences in isoforms may alter the effectiveness or safety of a treatment in individual patients.

In hospital pharmacy practice, AI can support patient-specific drug therapy by analyzing large amounts of clinical and biological information and helping healthcare professionals identify treatment options that are more appropriate for an individual patient. Such approaches may contribute to safer medication use, improved therapeutic response, and more individualized patient care. However, AI-generated recommendations should be carefully evaluated by healthcare professionals before being applied in clinical practice.

### **(3.9) AI-Based Prescription Review System**

Artificial intelligence (AI) is increasingly being used in prescription review to improve medication safety and support the rational use of medicines. In hospitals, AI-based systems can first check prescriptions for possible

problems before billing. The pharmacist then reviews the identified issues and makes the final decision. This approach combines the quick screening ability of AI with the clinical knowledge and experience of pharmacists.

AI-based prescription review systems can identify different types of medication-related problems, such as inappropriate indications, incorrect doses, unsuitable drug combinations, wrong routes of administration, contraindications, and problems related to special patient groups. A retrospective hospital study found that the use of an intelligent prescription review system was associated with a reduction in problematic prescriptions in outpatient and emergency departments.

These systems can help pharmacists identify prescription-related problems at an early stage and focus more on cases that require professional judgment. The use of AI for prescription review across hospitals and healthcare networks may also help improve the consistency of medication-review practices and the quality of pharmaceutical care. However, AI should be considered a supportive tool rather than a replacement for pharmacists. The final review and clinical decision should remain with the pharmacist [3].

### **(3.10) Drug Interaction Checking**

Drug interaction checking is an important application of AI in hospital pharmacy because interactions between medicines or between a medicine and other substances can alter therapeutic effectiveness and increase the risk of adverse effects. Such interactions may occur through pharmacokinetic mechanisms, affecting drug absorption, distribution, metabolism, or excretion. They may also occur through pharmacodynamic mechanisms, such as when two medicines produce opposing or additive effects at the same receptor or physiological pathway.

In clinical practice, the effect of a drug can also be influenced by concomitant medicines, certain foods, and interactions involving intestinal microorganisms. Therefore, identifying potential drug–drug interactions (DDIs) before medication administration is essential for improving medication safety. AI-based computational approaches can assist in predicting DDIs by



analyzing large and complex datasets that are difficult to evaluate through conventional clinical methods.

Several computational approaches have been explored for DDI prediction, including deep learning, network-based analysis, literature or text mining, matrix factorization, and similarity-based methods. These approaches can help identify possible interactions and provide useful information to pharmacists and other healthcare professionals during medication review. Clinical decision support systems can also generate alerts when potentially significant DDIs are detected, thereby supporting safer prescribing and dispensing practices.

AI-assisted DDI detection may therefore contribute to improved medication management by enabling earlier identification of potential interactions and supporting clinical decision-making. However, such systems should complement rather than replace the professional judgment of pharmacists and clinicians [5,17].

### **(3.11) Drug Information and Patient Counseling**

Providing accurate drug information and effective patient counseling is an important part of pharmaceutical care. Pharmacists help patients understand the purpose of their medicines, correct administration methods, possible adverse effects, relevant drug interactions, and precautions associated with treatment. Counseling should also consider the patient's medication history, allergies, lifestyle, and level of understanding.

Effective counseling should not be limited to simply giving instructions. Pharmacists should communicate with patients in a clear and understandable manner and encourage them to participate actively in decisions related to their treatment. The information provided should be adapted to the individual patient's needs, especially for those receiving long-term therapy or managing chronic diseases. Using open-ended questions can help pharmacists assess whether patients understand their illness and medicines, identify misconceptions, and provide appropriate clarification.

Artificial intelligence can further support patient counseling through chatbots and virtual health assistants. These tools can provide patients with accessible medication-related information, reminders, and general support for medication adherence. They may also provide

continuous assistance outside normal pharmacy hours. However, AI-based counseling requires careful supervision because inaccurate recommendations, data privacy concerns, algorithmic bias, and limited understanding of individual patient circumstances may affect the quality of care. Therefore, AI should complement rather than replace the pharmacist's professional judgment and patient-centered communication [5,13,14].

### **(3.12) Antimicrobial Stewardship**

Antimicrobial stewardship is an important approach for preventing and slowing the development of antimicrobial resistance. It focuses on selecting the most suitable antimicrobial agent and using the appropriate dose and treatment duration to effectively manage infections while minimizing toxicity and reducing unnecessary exposure that may promote the development of resistant microorganisms. Inappropriate or unnecessary antibiotic use remains a major concern and contributes to increasing antimicrobial resistance. Therefore, preserving the effectiveness of currently available antibiotics has become increasingly important, particularly because the development of new antimicrobial agents is a lengthy and challenging process.

#### **AI in Selecting Appropriate Antibiotics**

Antibiotic use is closely associated with the development of antibiotic resistance. Artificial intelligence has emerged as a potential tool for improving antibiotic prescribing and supporting efforts to reduce antimicrobial resistance. AI-based systems can analyze patient-related information and assist healthcare professionals in selecting more appropriate antimicrobial therapy. Antibiotic stewardship programs promote the responsible use of antibiotics, while clinical decision support systems can provide patient-specific recommendations and treatment-related information to support clinical decisions. These approaches can help improve prescribing practices and encourage more rational antibiotic use. However, continuous monitoring and intervention are necessary to maintain the effectiveness of antimicrobial stewardship programs.

#### **Resistance Prediction**

The increasing spread of antimicrobial-resistant microorganisms and the limited availability of effective



antibiotics represent a major healthcare challenge. AI and machine-learning techniques can assist in predicting antimicrobial resistance by analyzing bacterial genomic information and other relevant clinical data. Early identification of resistance patterns may help healthcare professionals make faster and more appropriate treatment decisions. Machine-learning models can be used to identify genetic characteristics associated with resistance and predict the resistance phenotype of bacterial pathogens. Such predictive approaches may support early antimicrobial selection and contribute to more effective antimicrobial stewardship [5,10].

### (3.13) Electronic Health Records (EHRs)

Implementing advanced EHR-based systems can strengthen clinical decision-making by identifying and alerting healthcare professionals to inappropriate medication use. By processing large volumes of patient information, AI can recognize treatment patterns and support safer prescribing decisions. It can also identify

patients who may be at greater risk of adverse drug effects through automated classification. In addition, patient-safety learning laboratory systems can detect, evaluate, and reduce risks linked to patient care.

Natural language processing and machine learning enable hospital information systems to retrieve and interpret unstructured data from EHRs. These records may include medication-safety information, patient medical histories, adverse drug reactions, drug interactions, medication errors, clinical outcomes, and pharmacokinetic consultation notes. Analysing such data supports proactive patient care and allows continuous assessment of medication effectiveness. As a result, EHR-based tools can help pharmacists and healthcare teams make more informed clinical decisions.

A related predictive approach developed by Balestra and colleagues identifies medication orders that may require intervention by examining the prescribing provider's prior interactions with the HER[12].

| Application Area | Main AI Contribution                                               | Expected Outcomes                                        |
|------------------|--------------------------------------------------------------------|----------------------------------------------------------|
| HER management   | Extraction, summarization, and structuring of clinical information | Reduced documentation burden and improved data usability |

[19].

## 3. CHALLAMGES AND LIMITATIONS

### 1. High initial investment:

Implementing AI and other digital technologies may require substantial spending on software, equipment, infrastructure, maintenance, and system upgrades. This can be difficult for hospitals with limited financial resources.

### 2. Requirement for proper training:

Healthcare professionals need adequate training before using new digital systems. Without sufficient knowledge and practice, staff may find it difficult to adapt to the technology and use it correctly.

### 3. Changes in existing workflow:

Introducing new technology can temporarily disturb routine pharmacy activities. Staff may need time to become familiar with new procedures, which can affect workflow during the early stages of implementation.

### 4. Technical failures and downtime:

Digital systems may occasionally stop working because of technical problems or system failures. During such periods, pharmacy staff may have to return to manual or paper-based procedures, which can interrupt normal services.

### 5. Difficulty in system integration:

AI or digital pharmacy systems may not always integrate smoothly with existing hospital information systems. Compatibility problems can lead to delays and may require additional technical support or infrastructure improvements.

### 6. Dependence on staff compliance:

The effectiveness of digital systems largely depends on how consistently healthcare workers follow the required procedures. For example, skipping barcode scanning or incomplete documentation can reduce the expected benefits of the technology.



7. Improved efficiency does not always mean better clinical outcomes:

Although digital technologies can make pharmacy operations faster and reduce medication-related errors, these improvements may not always lead to measurable changes in outcomes such as hospital stay or patient morbidity.

#### **8. Limited applicability across different hospitals:**

The performance of a digital system can vary depending on hospital size, available resources, infrastructure, and organizational practices. Therefore, results obtained in one healthcare setting may not be directly applicable to another.

#### **9. Possibility of bias in available research:**

Existing studies may have methodological limitations, such as the absence of suitable comparison groups or insufficient consideration of other factors that could influence the results. This makes it difficult to determine how much of the improvement is directly due to the technology.

#### **10. Insufficient long-term evidence:**

More research is needed to understand the long-term effectiveness, economic value, and sustainability of digital technologies in hospital pharmacy. Stronger comparative studies can provide clearer evidence about their lasting benefits and challenges [6,9,15].

### **4.FUTURE PERSPECTIVE**

#### **1. AI-Integrated Hospitals**

In the future, hospitals are expected to use AI more extensively for real-time analysis of patient information, early disease detection, predictive diagnosis, and individualized treatment planning. AI may integrate data from electronic health records, medical imaging, and wearable devices to support faster and more informed clinical decisions.

#### **2. Automation of Hospital Workflows**

AI can help automate routine administrative activities, resource allocation, and selected hospital operations. This may reduce repetitive work for healthcare

professionals and allow them to spend more time on direct patient care.

#### **3. Human–AI Collaboration**

Future AI systems are expected to support healthcare professionals rather than completely replace them. Pharmacists and other clinicians will continue to provide professional judgment, clinical interpretation, communication, and compassionate patient care while AI assists with data-intensive tasks.

#### **4. Smart Clinical Pharmacy Systems**

AI-based pharmacy systems may combine machine learning, data analytics, and clinical decision-support tools to improve medication management. These systems could analyze patient records and medication histories to identify drug-related problems and support appropriate therapy selection.

#### **5. Real-Time Medication Safety**

Advanced AI systems may continuously screen patient information to identify potential drug–drug interactions, allergies, inappropriate doses, and other medication-related risks. Such early identification could contribute to safer medication use in hospitals.

#### **6. Intelligent Inventory and Drug Distribution**

AI may improve hospital pharmacy operations by predicting medicine requirements, monitoring inventory, and supporting automated dispensing. Integration with robotics could further streamline medication distribution and reduce operational delays.

#### **7. AI-Based Patient Counselling**

Chatbots and virtual assistants may increasingly be used to provide medication-related information, support adherence, answer routine patient queries, and improve access to pharmaceutical care. Pharmacists would remain important for complex counselling and clinical decisions.

#### **8. Changing Role of Pharmacists**

As routine dispensing and administrative activities become increasingly automated, pharmacists may devote more attention to clinical activities such as medication



therapy management, patient counselling, therapeutic decision-making, and collaborative patient care.

## 9. Growth of AI in India

The review highlights the increasing development of AI in India through government initiatives, digital infrastructure, research activities, and the growth of technology-based startups. Healthcare is expected to remain an important area for AI implementation.

## 10. Need for Skilled Professionals and Ethical Implementation

For sustainable adoption of AI in Indian healthcare, challenges such as limited infrastructure, shortage of appropriately trained professionals, data-related concerns, and ethical issues will need to be addressed. Responsible implementation will be important for achieving safe and equitable AI-supported healthcare [4,17].

## CONCLUSION

Artificial intelligence is gradually becoming an important component of modern hospital pharmacy practice. Its integration into areas such as medication dispensing, prescription assessment, inventory control, pharmacovigilance, clinical decision support, antimicrobial stewardship, and personalized therapy can improve the accuracy and efficiency of pharmacy services. By processing and interpreting large volumes of clinical and operational data, AI can assist pharmacists in recognizing medication-related risks, supporting therapeutic decisions, reducing preventable errors, and improving patient care.

Despite these potential benefits, the adoption of AI in hospital pharmacy also presents several challenges. Concerns related to patient-data privacy, cybersecurity, implementation costs, algorithmic bias, transparency, and professional responsibility need to be addressed before widespread implementation. AI should be viewed as a decision-support tool that complements, rather than replaces, the knowledge, experience, and clinical judgement of pharmacists. Strong validation, appropriate governance, continuous monitoring, and adequate training are therefore essential for its safe and effective use.

In the coming years, advances in machine learning, predictive analytics, and data-driven personalized medicine may further broaden the applications of AI in hospital pharmacy. With appropriate infrastructure, research, regulatory frameworks, and collaboration among pharmacists, healthcare professionals, and technology experts, AI can help develop pharmacy services that are more efficient, accurate, and patient-focused. The future of hospital pharmacy is therefore likely to involve a collaborative approach in which AI handles data-intensive tasks while pharmacists retain responsibility for professional judgement and patient-center clinical care.

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