

## **Invited editorial**

# **Artificial Intelligence in Community Pharmacy: Redefining Professional Practice**

**Rajendra Sandur V, Mallige College of Pharmacy, 71, Silvepura, Bengaluru**

Artificial intelligence (AI) is rapidly becoming popular across healthcare sectors, including community pharmacy, where it is transforming the dispensing practices by automating repetitive tasks, enhancing precision, and improving patient safety [1]. AI-based technologies have already proven to have significant potential when it comes to minimizing medication errors and enhancing dispensing accuracy. The use of AI-based adherence tools has demonstrated encouraging positive changes in patient medication adherence [1]. Instead of taking the place of pharmacists, AI will act as a so-called trusted assistant that aids the clinical decision-making process, enhances the efficiency of the workflow, and helps pharmacists focus more on patient-centered care and counselling [2]. Moreover, pharmaceutical dispensing systems that are robotic in nature combined with the use of barcode scanning technology have made quite significant improvements in the safety and operational efficiency of pharmaceuticals in the community pharmacy setting [3,4]. Such systems are able to achieve a reduction in the dispensing error rates by over 50 percent with some studies reporting near zero dispensing errors [3,4]. Barcode verification ensures that the correct medication, dose, dosage form, and route of administration are verified before dispensing and thus reducing the risk of medication-related errors and adverse drug events [3]. Altogether, the current state of AI-based technologies is the promising future of pharmaceutical care in modern society in terms of accuracy and safety and the overall quality of pharmaceutical care [1,2].

# Key Applications of Artificial Intelligence in Community Pharmacy Dispensing

## 1. Robotic Dispensing Systems

One of the most popular AI-supported technologies to be used in community pharmacy practice is robotic dispensing systems. These systems enhance workflow, reduce human errors in medication handling and packaging, and enhance patient safety [3,4].

- **Reduction in Dispensing Errors:**

Sophisticated robotic machines like Vmax of ROWA have shown a significant decrease in the dispensing error rates, reducing the error to about 1.31 per cent to 0.63 per cent. These systems enhance medication safety and decrease the chances of adverse drug events [3].

- **Chaotic Storage Optimization:**

Modern robotic systems employ “chaotic storage” methods, in which medications are stored in

any available location within the system rather than in fixed compartments. The system effectively determines the precise whereabouts of the individual medication pack using barcode based tracking, thus maximizing storage space and allowing rapid access to the individual medication pack [4,5].

- **Improved Efficiency and Time Management:**

The robotic dispensing technologies are able to shorten the time of prescription handling to almost 23 seconds per prescription, whereas dispensing time is reduced to a minimum of around 23 seconds per prescription. They can save up to 30 hours of work per day in the high volume retail pharmacies and process about 100-150 or more medication items per hour [5].

- **Inventory and Stock Management:**  
Robotic systems with AI capabilities constantly check the stock level and update the stock data automatically, which helps reduce the number of stock-out cases and increase the efficiency of inventory management [3].
- **Enhanced Safety Protocols:**  
Integrated barcode verification in robotic systems ensures that the right medication, strength and dosage form are dispensed, and chances of incorrect dispensing errors are reduced to almost zero [3,4]

## 2. Computer Vision for Medication Verification

AI-enabled computer vision systems use deep learning algorithms to inspect, classify, and verify medications in real time, replacing slower and more error-prone manual inspection processes.

Technologies based on models such as YOLO are increasingly used in pharmaceutical quality assurance and dispensing verification [6].

### Key Applications and Technologies

- **Blister Pack Inspection:**  
Artificial intelligence (AI) systems, such as DeepInspect and Cognex, can detect defects including missing tablets, broken or chipped pills, duplicate fill, empty cavities, foil defects, and incorrect markings in blister packs. They have a high conveyor speed and can also utilize 3D imaging technologies to measure seal integrity and packaging quality [7,8].
- **Pillbox and Pouch Verification:**  
Automated verification systems scan images of individual drugs and match them with large reference databases to verify that the appropriate medication has been packed to the patient [6,7].

- **Defect Detection:**

Advanced AI systems can detect anomalies based on pill size, color, shape, and imprint characteristics, achieving detection accuracies exceeding 95%, thereby enhancing dispensing reliability and patient safety [6,7].

### **3. Automated Workflow and High-Speed Dispensing**

The workflows of automated dispensing involve AI to streamline the entire medication dispensing process, which involves the receipt of a prescription, and the packaging and delivering of the drugs [1,2].

#### **Key Features of Automated Workflow Systems**

- **End-to-End Automation:**

Automated systems control various dispensing processes, such as processing electronic prescription (e-prescription), picking, counting, labeling, packaging, and storage,

thus reducing the necessity to be manually operated [2]. Such systems can be utilized in high-density pharmacy settings and can dispense about 100-150 items per hour [5].

- **Robotic Efficiency with Barcode Verification:**

Robotic dispensing systems like the Omnicell XR2 system are used to fill, label, manage inventory and deliver with 100 percent barcode scanning to reduce human error and enhance dispensing efficiency. The barcode scanning makes sure that all the medication is checked before it is dispensed to ensure that the medication can be matched up with the prescription. In addition, integrated imaging systems assess pill size, shape, and color before unit-dose packaging [3,8].

- **Diverse Pharmaceutical Applications:**

Automated systems are used both in dispensing oral solid dosage form and in storage of medication, returns, restocking, unit-dose packaging and in some healthcare facilities, preparation of hazardous medications such as sterile chemotherapy agents [2].

#### **4. Automated Prescription Review**

Machine learning (ML) algorithm-based automated prescription review systems help improve medication safety by analysing the prescription and patient-specific clinical information. These systems are able to detect dosing errors, possible drug-drug interactions (DDIs), contraindications and adverse drug reactions [9,10]. Using a combination of electronic health records (EHRs), laboratory reports, and medication histories, AI-assisted prescription review systems help to optimize therapeutic outcomes, increase drug efficacy, and decrease medication-related errors. These

technologies are also useful in assisting the pharmacists with the clinical decision-making and promote safe and personalized pharmaceutical care [2].

#### **Key Capabilities of Automated Prescription Review**

Automatic prescription review systems based on Artificial Intelligence (AI) and machine learning (ML) are increasingly being integrated into community pharmacy practice to enhance medication safety, optimize therapeutic outcomes, and support clinical decision-making. They are systems that process patient-specific clinical data, drug histories, and lab reports to detect possible medication-related issues in real time [1,2].

- **Drug-Drug Interaction (DDI)**

##### **Detection:**

To identify potentially dangerous drug-drug interactions, machine learning models can process large and complex data, such as molecular structures,

pharmacokinetic parameters, and clinical records. The systems that are AI-assisted are beneficial in helping pharmacists to identify contraindicated combinations and also reduce the risk of adverse drug reactions [9,10].

- **Optimal Dosing Recommendations:**

Individualized doses of medications due to age, weight, physiological functioning, and comorbidities can be predicted using AI algorithms combined with physiologically-based pharmacokinetic (PBPK) models. This method is particularly useful in oncology where individualized dosing of chemotherapy is crucial to ensure the maximum efficacy and minimal toxicity [2].

- **Clinical Decision Support Systems (CDSS):**

Machine learning tools like the

Random Forest algorithm provide real-time assistance to pharmacists and prescribers by detecting inappropriate prescribing behaviours, recommending safer therapeutic options, and enhancing medication safety [2,9].

- **Error Detection in Complex Clinical Scenarios:**

AI-based systems could detect mistakes related to prescribing, dispensing, and administration of medicine, such as wrong dosage form, route of administration, and inappropriate dosing regimens. They are particularly useful in polypharmacy, or high-risk patient groups [9,10].

### **AI-Enabled Personalized Pharmaceutical Care and Clinical Decision-Making**

Artificial Intelligence is increasingly shifting community pharmacy practice from a traditional dispensing-centered

model toward personalized pharmaceutical care [1,11]. AI systems can also help pharmacists make personalized treatment recommendations and maximize patient outcomes by incorporating patient-specific clinical data, medication history, lab parameters, pharmacogenomic information, and lifestyle risk factors [2,12].

AI-powered clinical decision support systems (CDSS) can analyse large volumes of healthcare data in real time to identify potential drug-related problems, predict adverse drug reactions, recommend dose adjustments, and improve therapeutic monitoring. In the treatment of chronic diseases like diabetes, hypertension, cardiovascular diseases, asthma and mental health disorders, which require ongoing drug optimization and monitoring for adherence, these technologies have been found as particularly useful [2,9].

In addition, AI-powered predictive analytics may help identify patients at risk

of not taking their medications, hospitalization or adverse drug events. This allows pharmacists to make early interventions, target counselling, and follow-up strategies to make a difference [13,14]. Pharmacogenomics along with AI can also potentially contribute to precision medicine by forecasting a patient's response to specific medications and reducing the risk of drug side effects [12].

Virtual AI assistants and conversational chatbots are also emerging as supportive tools in community pharmacy practice. These systems can provide medication reminders, answer basic drug-related queries, offer multilingual counselling support, and improve accessibility of pharmaceutical care, particularly in underserved populations [13,15].

Importantly, AI isn't replacing pharmacists, but it is augmenting their professional skills by helping to minimize the amount of administrative work they do and allowing them focus more on cognitive

and clinical work. Thus, AI is transforming the pharmacist's role beyond dispensing medications to becoming a technology-driven clinical care provider with an active involvement in personalized patient care and preventive healthcare services [1,2].

### **AI-Driven Inventory Management**

In the pharmaceutical industry, AI-driven inventory management systems are revolutionizing the supply chain by enhancing demand forecasting, reducing medication wastage, and optimizing stock levels. These systems draw on past use data, seasonal fluctuations, epidemiological data and patient demographics to accurately forecast the demand for medication [1,11].

### **Key Benefits and Functionalities**

- **Predictive Analytics:**  
Machine learning algorithms analyse historical dispensing data and identify usage patterns to forecast future medication

requirements with high accuracy [1,11].

- **Reduction in Waste and Operational Costs:**

Optimized inventory control helps keep stock levels from running too high and prevents meds from expiring, thus cutting down on financial losses and pharmaceutical waste. [3]

- **Real-Time Inventory Optimization:**

AI-powered systems automatically adjust stock levels based on patient demand, prescription patterns, and market dynamics, preventing drug shortages.

- **Improved Operational Efficiency:**

Automation of procurement processes and stock monitoring minimizes human error, optimizes pharmacy workflow and guarantees

timely supply of critical medications [2,5].

- **Public Health Forecasting**

**Applications:**

Electronic health records (EHRs) and epidemiological data can be input into AI systems to anticipate surges in the demand for precise drugs in the event of disease outbreaks or seasonal conditions like flu [2].

### **Smart Adherence Tools**

The smart adherence technologies involve AI-powered applications, sensors and connected devices that enhance patient medication adherence by providing tailored monitoring and reminders. These systems are able to improve therapeutic outcomes by detecting the patterns of non-compliance and making timely interventions [13,14,15].

### **Types of Smart Adherence Tools**

- **Smart Pill Bottles and Automated Dispensing Systems:**

They are devices that are able to sense the opening of a bottle and provide a visual or audio warning when the patient is supposed to take a medicine. A few systems also provide adherence data to healthcare providers or caregivers [15].

- **AI-Powered Medication Adherence Applications:**

Medication adherence can be enhanced by personalized medication reminders, symptom monitoring, and medication interaction alerts, which are all features that can be incorporated into mobile applications like Medisafe and MyTherapy [13,15].

- **Ingestible Sensor Technologies:**

Oral dosage forms with ingestible sensors that emit signals when the drug is dissolved in the

gastrointestinal tract could help confirm that the drug was taken [16].

- **Wearable Sensing Systems:**

There are wearable devices with motion sensors that can detect and monitor medication-taking behaviour in real-time [15].

- **AI Chatbots and Virtual Assistants:**

Patient education, medication counselling, and adherence support are made possible by AI-powered chatbots, which offer interactive and personalized communication as well as automated follow-up reminders [13].

These AI-enabled tools are transforming community pharmacy practice, from boosting accuracy in medication dispensing to ensuring patients stay on their medication, while also streamlining inventory management and drug coverage planning.

## **Conclusion**

Artificial Intelligence (AI) is a technology that is rapidly shaping the practice of community pharmacy, with benefits in terms of increased ease of dispensing, increased medication safety, enhanced workflow efficiency, and increased patient-focused pharmaceutical care. The role of AI in these healthcare real-time systems is evident, with several technologies already showing significant promise in minimizing medication errors, increasing efficiency, and boosting therapeutic results. The potential benefits of AI-assisted technologies, like robotic dispensing systems, computer vision verification, automated prescription review, predictive inventory management, and smart adherence tools, in these healthcare real-time systems are profound, with many of these technologies demonstrating significant promise in reducing medication errors, improving operational efficiency,

and enhancing therapeutic outcomes. Most importantly, AI should be seen as a tool for pharmacists and not as a replacement for them. Automating repetitive and time-intensive tasks allows AI to free up time for pharmacists, allowing them to focus on clinical duties, patient counselling, medication therapy management, and preventive health care services. As a result, the scope of the professional function of community pharmacists is changing from dispensing medications to providing technology-enabled clinical services and customized pharmaceutical care. While these benefits are promising, the potential barriers to implementing AI, such as the cost of implementation, data privacy and security, ethical considerations, and technical training, need to be taken into account to ensure that the use of AI in pharmacy practice is safe and effective. The future of community pharmacies will continue to be shaped by technological advancements, particularly in the field of AI. AI's impact extends beyond enhancing

patient care to influencing the way healthcare is managed and delivered. As AI continues to evolve, its future impact on community pharmacies is projected to further transform their role in healthcare. AI's influence isn't limited to improving patient service; it is reshaping the healthcare sector as a whole. In summary, the use of AI is a game-changer for the delivery of pharmaceutical care in today's healthcare systems, contributing to safer, more efficient, and patient-centric treatment.

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