

Integrating Artificial Intelligence into Automated Pharmacy Dispensing: Opportunities and Public Health Implications: A Mini-Review

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Abstract

The global healthcare system is going through a big evolution in technological innovation. These evolutions include the integration of artificial intelligence (AI) into the pharmaceutical sector. These changes have shaped the shape of traditional pharmacy practice and services, especially AI-powered automated dispensing systems (ADSs) such as pharmacy vending machines, which have a huge potential in improving accessibility to medications, particularly in remote areas. ADSs have the potential to improve accuracy, reduce medication errors, and optimize inventory. These systems, when integrated with AI algorithms, can provide up-to-date features such as user-specific recommendations for medications and other health products, ID verification for controlled drugs, and real-time inventory management, in addition to the integration with patient medical records. Furthermore, AI-enabled symptom checkers and chatbots embedded in such systems can help patients and users in self-assessing minor illnesses and injuries and selecting the suitable over-the-counter medications without direct pharmacist involvement. This review article surveys and explores the current state, opportunities, and challenges of integrating AI into automated pharmacy dispensing systems. It examines their impact on public health outcomes and provides recommendations for safe, ethical, and effective implementation.

Keywords: *Pharmacy, artificial intelligence, automated dispensing systems, dispensing, over-the-counter medications.*

1. Introduction

The global healthcare system is going through a big evolution in technological innovation. These evolutions include the integration of artificial intelligence (AI) into the pharmaceutical sector. Which changes the shape of traditional pharmacy practice and services? Especially AI-powered automated dispensing systems such as pharmacy vending machines, which have a huge potential in improving accessibility to medications, particularly in remote areas.

Automated dispensing systems have the potential to improve accuracy, reducing medication errors and optimizing inventory^[1-3]. These systems, when integrated with AI algorithms, can provide up-to-date features such as user-specific recommendations for medications and other health products, ID verification for controlled drugs, and real-time inventory management, in addition to the integration with patient medical records^[4,5]. Furthermore, AI-enabled symptom checkers and chatbots embedded in such systems can help patients and users in self-assessing minor illnesses and

injuries and selecting the suitable over-the-counter (OTC) medications without direct pharmacist involvement^[6,7].

In the context of public health, these innovations offer respective benefits such as ensuring 24/7 availability of essential medications, especially in remote areas or in places where there's no pharmacy nearby. In addition, it helps in promoting medication adherence and providing accurate patient education through interactive interfaces^[8]. In low- and middle-income countries (LMICs), where traditional pharmacy infrastructure may be limited, these technologies can be considered as a scalable and cost-effective solution for expanding pharmaceutical care^[9]. However, one of the main concerns is ethical use, over-dependence on AI, data security, and the regulations required to ensure patient safety^[10,11].

This review article surveys and explores the current state, opportunities, and challenges of integrating AI into automated pharmacy dispensing systems. It examines their impact on public health outcomes and provides recommendations for safe, ethical, and effective implementation.

2. Types of AI Integration in Pharmacy Dispensing Systems

The integration of artificial intelligence (AI) into pharmacy dispensing systems such as pharmacy vending machines has evolved to become a versatile approach that improves patient interaction, decision making, inventory control, and machine learning. These AI implementations are implemented in smart kiosks, pharmacy vending machines, and robotic dispensing units, creating a class of "autonomous pharmacy systems" which can be utilized with minimal human intervention [12]. When implemented, the quality of the services provided by these machines will be greatly improved, and human error will be reduced to a minimum.

3. AI Chatbots and Symptom Checkers

One of the most promising integrations of AI in pharmaceutical services is the utilization of symptom checkers. These tools, which are integrated into mobile applications or pharmacy vending machines, use algorithms and natural language processing (NLP) to help users in choosing the most suitable OTC medication for their respective cases based on the symptoms reported by them [6,11]. For example, the HERMES Kiosk System implements a multilingual AI chatbot that can guide patients through minor illnesses self-assessment and selection of OTC products, while maintaining patient privacy [7].

4. AI-Based ID Verification and Controlled Access

To ensure regulatory compliance and minimize the misuse of restricted and controlled drugs, some systems use ID scanning in addition to AI-driven facial recognition. These features ensure verifying patient identity before allowing access to age-restricted or limited-supply drugs, adding another layer of security to dispensing systems [7].

5. Predictive Analytics and Inventory Optimization

Machine learning (ML) algorithms are increasingly utilized in predicting medication demands, optimizing stock control, and reducing medication waste. These systems analyze sales data and seasonal patterns to give restocking schedules, recommend purchases, and minimize waste and over-ordering [4]. In mega-scale healthcare systems, such as those using BoxPicker® or PillPick®, these AI tools are also utilized in real-time stock redistribution across locations [13].

6. Voice Interfaces and Multilingual Accessibility

Most of the AI systems are designed with voice-activated commands that have multilingual options, which is useful in low-literacy populations or multilingual communities. These user interfaces work with patients in understanding drug indications, interactions, side effects, and contraindications, which results in improved safety and medication adherence [5].

7. Pharmacovigilance and Usage Monitoring

Some pharmacy vending machines that are integrated with AI have built-in pharmacovigilance modules that record adverse drug

reactions reported by patients and can detect abnormal usage patterns, which indicate misuse. These systems send an alert or notification to central monitoring centers or public health authorities, and that makes it an essential tool in medication safety surveillance and public health data collection [14]. The AI implementation in pharmacy vending systems continues to grow rapidly, reflecting a shift from classic dispensing models to interactive, intelligent care platforms that function at the intersection of safety and patient empowerment.

8. Use Cases and Global Examples

The integration of artificial intelligence (AI) with pharmacy vending machines has already been implemented across various healthcare systems worldwide. These utilizations are considered to be a proof of concept for improving medication accessibility and enhancing medication safety. While developed countries have led in the application of such technologies, low- and middle-income countries (LMICs) are increasingly interested and are experimenting with this new model of delivering medications.

8.1. United States: Hospital-Based Automation

Hospital pharmacies in the United States are implementing robotic dispensing systems on a wide scale, such as BoxPicker®, PillPick®, and ROWA®, and these systems are usually integrated with predictive AI software for inventory management and control and error reduction [1]. The utilization of these systems has resulted in reducing medication and dispensing errors significantly, which gave the pharmacist more time to focus on his clinical and counseling role [2].

8.2. Japan: Advanced Robotics in Community Pharmacies

Japan is one of the countries that has developed and implemented highly automated systems in both hospital and community pharmacies. One of which is the Mini DimeRo® robotic system, in addition to barcode-verification-based medication dispensers, which are used to record and manage large volumes of prescriptions with high precision and efficiency [3]. These systems are merged with AI for workflow management and patient-specific customization. Managing a large volume of prescriptions reduces the time required to obtain medicines, and the addition of barcode readers will give the chance to implement a wide variety of medications to be dispensed, like antibiotics and CNS medications.

8.3. South Korea: AI Vending for OTC and Minor Ailments

South Korea is another country that has piloted smart vending machines that dispense OTC medications based on AI-guided symptom checkers, minimizing unnecessary visits to doctors for minor illnesses [15]. These dispensing system machines are usually installed in public places such as transportation hubs, providing 24/7 access while collecting real-time usage data for public health surveillance. In addition, it reduces the number of visits for doctors and pharmacists working in community pharmacies, and thus it gives them room to focus on more serious conditions.

8.4. United Arab Emirates: AI-Powered Kiosks with ID Verification

The UAE has installed pharmacy vending machines in malls, airports, and metro stations; some of these vending machines come with facial recognition systems that use AI in addition to Emirates ID verification. These features help in ensuring dispensing of a limited range of medications while at the same time promoting consultations with pharmacists via integrated video systems [16].

8.5. India: Smart Medicine Dispensers in Rural Settings

In India, low-cost pharmacy vending machines integrated with AI telemedicine are widely being used in rural and remote areas where access to pharmacies is limited. These vending machines are integrated with video consultations, e-prescriptions, and automated medicine dispensing, filling a big gap in pharmaceutical services in India [17]. Countries with high populations, like India and other countries, can benefit from the pharmacy vending machines because they can manage a large number of patients effectively, resulting in reduced mortality rates, especially in rural areas where it's often hard to access a healthcare facility.

8.6. Africa: Pilot Studies and Adaptation Potential

Countries such as South Africa, Kenya, and Nigeria are testing the feasibility of AI-enabled pharmacy vending machines. Services such as mobile health vans and telepharmacy booths are using semi-automated pharmacy vending machines with AI integration in the future [18]. These technologies address scalable solutions for regions with limited resources and a shortage of healthcare professionals. These global use cases reflect the growing recognition and importance of AI-enabled pharmacy vending machines and dispensing systems as a complementary model to traditional pharmacy care. Their success depends on the alignment of technology, regulation, infrastructure, and local health needs, in addition to the collaboration with healthcare authorities.

9. AI Algorithms in Vending Machines for Diagnosing Minor Illnesses

One of the most innovative applications of artificial intelligence (AI) in automated pharmacy systems is the merging of diagnostic algorithms within vending machines. These systems utilize rule-based logic, symptom-checker databases, and machine learning (ML) to support the identification of minor illnesses and thus recommend appropriate over-the-counter (OTC) medications. Such smart vending machines help in reducing unnecessary visits to healthcare facilities, empowering self-assessment, and enhancing access to timely treatment.

9.1. Natural Language Processing and Chatbots

Advanced pharmacy vending machines integrate natural language processing (NLP) chatbots that are capable of engaging users in interactive health dialogues. These chatbots can translate free-text or voice inputs to understand symptoms, duration, and severity of illness. Such features allow for a more precise assessment of minor ailments such as headaches, sore throats, allergies, or mild gastrointestinal symptoms [15].

9.2. Machine Learning for Continuous Improvement

Some pilot systems use machine learning models trained on anonymized health interaction data. These models refine their diagnostic precision with continuous usage over time based on user inputs, feedback loops, and pharmacist-reviewed outcomes [17]. Federated learning approaches have also been proposed to allow algorithm updates without affecting user privacy, especially in public health-sensitive settings [19].

9.3. Integration with Pharmacovigilance and Safety Protocols

To reduce risks of incorrect self-assessment, AI algorithms can incorporate safety thresholds or "red flag" triggers that notify the vending machine if concerning symptoms are reported (e.g., high fever, chest pain, prolonged symptoms). In such cases, the machine may suggest seeing a healthcare provider or offer a teleconsultation service [7]. Moreover, these systems may collect adverse drug

reaction (ADR) data or patterns of frequent self-medication for public health monitoring and pharmacovigilance.

9.4. Examples of Implementation

The HERMES vending machine that was piloted in the Gulf region and Southeast Asia, integrates multilingual NLP symptom-checking software, facial recognition, and federated learning AI modules to help guide medication dispensing [19]. In South Korea and the UAE, public health authorities have supported smart vending machines that perform minor illness assessment with options for OTC delivery or pharmacist consultation [9]. Despite the fact that it is not considered a replacement for professional diagnosis, these algorithmic systems offer a scalable, low-barrier entry point to healthcare, especially for populations with limited access to clinics or pharmacists, and there is a big room for future improvements.

10. Challenges and Concerns

High Costs and Infrastructure Requirements: The large investment needed for AI-enabled pharmacy kiosks, including hardware, AI software, and continuous maintenance, is a major barrier, especially for smaller clinics or pharmacies in low-resource settings. Integration with existing systems comes with complexity and high cost [20].

Data Quality, Privacy and Security: AI systems depend on high-quality, well-curated patient data. At the same time, they must adhere to strict privacy standards (e.g., GDPR, HIPAA), which complicates utilisation and data sharing between platforms [21].

Algorithmic Bias and Opacity: Deep learning models often function as "black boxes", making it difficult to explain or audit their decision-making. This undermines trust and may raise bias if training datasets are unbalanced or inefficient [22].

Operational Reliability and Safety Risks: AI modules may misinterpret symptoms or dispense incorrect medications; mechanical failures or system shutdown can compromise safety and access [23].

Workforce Adaptation and Resistance: Healthcare professionals may resist adopting AI-driven systems due to concerns about job security or a lack of digital literacy. Training and change management are essential to ensure smooth transitions [24].

The collaboration between investors and healthcare authorities can minimize the risks of implementing such high-cost services by providing a rigid infrastructure to install and establish such services. The merger between tech companies and healthcare companies will also result in effective and usable technologies.

11. Regulatory and Ethical Considerations

Medical Device Regulations (SaMD): AI-driven dispensing systems are often considered as Software, requiring validation and compliant documentation for authorities. Emerging reporting frameworks such as TRIPOD-AI, CONSORT-AI, and DECIDE-AI are gradually targeting these technologies [25].

Consent and Biometric Data Usage: Systems using biometric verification (e.g., facial recognition) must ensure transparent consent processes and robust safeguards for identity data [26].

Ethical Principles in AI Design: Ethical AI must have autonomy, justice, beneficence, and non-maleficence. Transparency, fairness,

and equitable access are crucial to safeguarding users, particularly in sensitive health domains [27].

Regulatory Fragmentation: While regions like the EU apply strict data protections (GDPR), other jurisdictions, including parts of the U.S., lack unified AI-specific healthcare policies, creating regulatory uncertainty [25].

These regulatory uncertainties limit the establishment of pharmacy vending machines and reduce the accessibility of medications, especially in rural areas.

12. Future Directions

Integration Clinical Systems: Connecting AI kiosks to Electronic Health Record systems improves personalization, adherence tracking, and decision support, but it also demands standardized data governance [28].

Human-Centered AI Design: Engaging pharmacists and end-users in the design process, providing explainable AI output, simplified user interfaces, and trust-building features, supports safer adoption and collaboration [29].

Accessibility: Future systems should implement multilingual voice interfaces, large text, and assistive accessibility (e.g., Braille) to support low-literacy users and comply with universal design standards [30].

Scalable Deployment in LMICs: Modular, cost-effective AI pharmacy vending machines adapted for low- and middle-income countries provide promise for increasing pharmacy access in underserved areas. Pilot studies in rural and primary care settings support usability analysis [31].

Training and Digital Literacy for Pharmacy Staff: Building AI proficiency through continuing education and professional development ensures that pharmacists remain critical overseers of AI recommendations and maintain core clinical competencies [32].

13. Public Health Benefits of Integrating AI with Automated Pharmacy Dispensing

The world is currently undergoing a significant and sophisticated transformation in the integration of artificial intelligence with automated medication dispensing. Remarkably, this integration has revealed public health benefits that we, as pharmacists, could not have imagined in the past. These benefits have been proven by several recent research studies

For example, a study that was conducted in 2025 by Salime et al. systematically reviewed automation models implemented in hospital pharmacies and found that integrating AI-driven verification with automated dispensing significantly reduced medication errors, improved workflow efficiency, and enhanced overall patient safety. The authors reported that hospitals adopting these systems experienced faster dispensing turnaround times, more accurate inventory tracking, and better allocation of pharmacists' time toward clinical care rather than manual preparation tasks [20].

Similarly, a 2023 study by Tu et al. demonstrated that automated dispensing cabinets combined with AI alert systems in intensive care units led to a 40% reduction in dispensing errors, highlighting the critical role of technology in enhancing medication safety in high-risk settings [33].

Furthermore, Gao and colleagues (2023) conducted a 14-year retrospective analysis in a large hospital outpatient pharmacy

and found that continuous refinement of automation systems correlated with sustained decreases in both dispensing time and medication wastage [34].

Additionally, a 2024 study published in *Frontiers in Medicine* emphasized that AI algorithms embedded within pharmacy dispensing systems can proactively detect clinical prescribing errors, thereby preventing potential adverse drug events before they occur [35].

Prescribing errors are common in hospitals and healthcare settings. The implementation of a system that can detect these errors will greatly reduce the mortality rate and improve the quality of services provided by the hospital.

14. Declarations

Ethical Clearance

Not applicable.

Conflict of interest

The authors declare that there is no conflict of interest

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Contributors

MSM, AAHO, and BAY: Conceived the idea for the review, and designed the structure. MSM, and AAHO: Performed the literature search, data collection, and initial drafting of the manuscript. YSK, and BAY: Contributed to data analysis, interpretation, and critical revision of the content. BAY: Supervised the study. All authors contributed to writing, provided intellectual input, revised the manuscript critically for important content, and approved the final version for publication.

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