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

OPEN ACCESS

Review Paper

Artificial Intelligence in Clinical and Community Pharmacy Practice: Transforming Medication Safety and Patient Care

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ARTICLE INFO

Published: 25 Sept 2026
Keywords:
Artificial Intelligence, Pharmacy Practice, Safety, Patient Care
DOI:
10.5281/zenodo.22953585

ABSTRACT

Walk into most hospital or community pharmacies today and artificial intelligence is, in some form, already part of the workflow quietly supporting clinical decision-making, catching medication-safety problems, nudging adherence, and shaping how pharmacists engage with patients directly. This review pulls together what the current literature says about that practice-facing side of AI: clinical decision support systems, adverse drug reaction and drug-drug interaction detection, computerized prescriber order entry, dose optimization, identification of potentially inappropriate prescribing, medication error detection, electronic health record integration, medication adherence technologies, automated dispensing, and tele pharmacy (1,2). Taken together, the evidence points in a fairly consistent direction: these tools can cut medication errors, sharpen dosing precision for high-risk medications, strengthen adherence among patients managing chronic disease, and free up pharmacists to spend more time on direct patient care rather than repetitive, manual tasks. Robotic dispensing is a good illustration studies link it to substantial reductions in both preventable and unpreventable errors, and one large health system has reported preparing several million doses without a single dispensing error (2,3). That said, the literature is just as clear about what still stands in the way of safe, equitable adoption at the point of care: patient data privacy, algorithmic bias rooted in unrepresentative training data or pre-existing healthcare disparities, poor interoperability with the clinical systems already in place, and real gaps in workforce readiness. None of that resolves on its own this review concludes that getting AI integration right will take sustained investment in AI literacy and education, alongside deliberate work to build trust between clinicians, patients, and the tools themselves.

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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.

INTRODUCTION

Pharmacy practice covers a lot of ground: medication reconciliation, medication review, medication therapy management, drug information, patient education, adverse drug reaction (ADR) monitoring, interprofessional collaboration. As prescription volumes climb and drug regimens grow more complex, the administrative load on pharmacists has grown right along with them, which is a large part of why demand for technological support keeps rising(2)

Healthcare has been one of the biggest beneficiaries of advances in machine learning (ML) and deep learning (DL), and the shift has been more than incremental — these tools have pushed AI past simple algorithmic automation and into genuinely personalized medicine, shaping clinical decision-making, disease diagnosis, and predictive practice along the way. The result has been sharper diagnostic accuracy, smoother provider workflows, and, on the whole, better patient outcomes (2).

Most of the attention AI has received in pharmacy has gone to drug discovery and industrial research and development. Its role in day-to-day practice adherence support and patient education especially — has, until fairly recently, stayed comparatively underexamined. That gap matters: closing it is what allows AI technologies to be woven more fully into quality of care and patient engagement across both hospital and community settings. This review sits squarely in that practice-facing space the tools that support pharmacists and patients directly, at the point of prescribing, dispensing, counselling, and ongoing chronic disease management. A companion review takes up the earlier part of the medicine's lifecycle discovery, trials, industrial development; this one picks up where that leaves off, once a medicine reaches the pharmacist and the patient.

SCOPE AND OBJECTIVES

This review is deliberately bounded to the downstream, post-dispensing segment of the medicine lifecycle — routine pharmaceutical care as it is delivered inside hospital and retail pharmacies. It does not address drug discovery, pre-clinical testing, manufacturing, or clinical trial design, each of which is addressed in a separate companion review. Within this bounded scope, the paper pursues three objectives:

- To evaluate how AI-enabled tools minimize active medication and prescription errors at the point of care, including CDSS, ADR and DDI detection, CPOE, and dose optimization.
- To analyze the shifting workflow dynamics inside physical hospital and community pharmacies, including automated dispensing, inventory management, tele pharmacy, and adherence technologies.
- To critically appraise the practice-level risks — including algorithmic bias in dosing recommendations, patient data privacy, pharmacist accountability, and workforce training gaps — that must be resolved before these tools can be considered safe and equitable at the point of care.

AI TOOLS SUPPORTING THE PHARMACY WORKFLOW

The common thread across the tools described below is speed at scale: AI and machine learning let pharmacists work through medical records, laboratory results, and medication profiles far faster than manual review would allow, flagging potential drug interactions, weighing the safety and efficacy of medicines, and generating recommendations tailored to the individual patient in front of them (2).

CLINICAL DECISION SUPPORT SYSTEMS (CDSS)

A clinical decision support system is designed to improve healthcare delivery by supplementing clinical decisions with targeted knowledge, patient information, and other relevant health data. Individual patient characteristics are matched against a computerized knowledge base, and patient-specific assessments or recommendations are then presented to the clinician. This technology enables pharmacists to sift through large volumes of data and intervene to prevent medication errors, reduce patient complications, and generate cost savings (2). A machine learning-based clinical decision support system developed to flag prescriptions carrying a high risk of medication error has demonstrated that such tools can be integrated directly into prescribing workflows rather than functioning only as retrospective audit systems (12). A recent narrative review similarly concludes that AI-enabled decision support is among the most matureand widely adopted applications of AI within clinical pharmacy, spanning drug safety, workflow support, and precision-medicine use cases (5); a separate 2025 review of real-world deployments across community, hospital, and industry pharmacy settings reaches a broadly similar conclusion, while cautioning that reported error-reduction figures vary widely by institution and are rarely benchmarked against a common comparator (8).

ADVERSE DRUG REACTION (ADR) DETECTION

AI has been extensively applied to the prediction and detection of ADRs at the point of care. Deep neural networks combined with toxicogenomic and pharmacovigilance databases have been used to estimate the likelihood of ADRs, achieving mean validation accuracies in excess of 89%. Decision-tree induction methods have achieved predictive accuracies of 78.9-90.2% for allergic, renal, central nervous system, and hepatic ADRs, while machine learning-based clinical decision support tools generate objective risk scores by integrating severity scales with probability algorithms

(2). A 2022 scoping review of 78 studies identified a wide range of use cases in which AI could plausibly reduce the frequency of adverse drug events across the medication-use process, though it also found the evidence base to be heterogeneous in methodology and outcome reporting, limiting direct comparison between approaches (15). Risk-classification models have extended into more specialized domains as well; one clinician-validated model built to classify patients by their level of risk of opioid use disorder illustrates how the same underlying techniques used for general ADR prediction can be adapted to a specific, high-stakes prescribing decision (14).

A wide variety of computational approaches has been applied to ADR prediction in practice settings, including logistic regression classifiers incorporating the structural properties of drugs, random-walk algorithms applied to drug-ADR interaction networks, and knowledge graphs linking drugs, protein targets, indications, and adverse reactions. Natural language processing has similarly been used to extract adverse drug events from unstructured clinical narratives, automating pharmacovigilance processes that would otherwise depend on labour-intensive manual review (2).

RUG-DRUG INTERACTIONS (DDIS)

Drug-drug interactions (DDIs) are a major driver of ADRs in their own right, and they add meaningfully to the healthcare cost burden. Predicting them well means pulling together multiple drug characteristics alongside known interaction data from resources like DrugBank, SIDER, TWOSIDES, and the Kyoto Encyclopedia of Genes and Genomes. The computational methods split roughly into similarity-based, network-based, and machine learning-based approaches, and the large-scale predictors tend to combine several similarity measures at once — molecular structure, pharmacophoric, and target similarity — inside support vector machine classifiers to get high predictive accuracy (2).

COMPUTERIZED PRESCRIBER ORDER ENTRY (CPOE)

Medication errors are still one of the most common sources of harm in healthcare, and a lot of them trace back to fairly mundane causes: drug names that look alike, prescriptions that are hard to read, abbreviations that get misread. Computerised prescriber order entry (CPOE) systems tackle this head-on by letting physicians enter and transmit orders electronically instead of relying on paper charts or verbal instructions. Controlling how medication histories are selected, displayed, and stored cuts down on transcription errors — though, worth noting, it also opens the door to new kinds of prescribing and dispensing error that then need to be managed in their own right (2).

DOSE RECOMMENDATION AND OPTIMIZATIONS

Dosing is another area where personalization pays off. Machine learning-based recommendation systems pull in data from safety and effectiveness metrics, electronic health records, and treatment history to fine-tune efficacy while keeping side effects down, and reinforcement learning in particular has shown promise adjusting dosages for precision

cancer treatment — chemotherapy dosing platforms that track response over time have gotten measurably more precise as a result (2).

High-risk, narrow-therapeutic-index medications are where this matters most. For vancomycin, machine learning-assisted dosage titration has outperformed the traditional pharmacokinetic models, especially in the hands of less experienced clinicians who benefit most from the extra guidance. Similar prediction models built for digoxin and warfarin have helped head off adverse events caused by dosing errors — evidence, collectively, that these techniques generalize well across a range of medications were getting the dose wrong carries real consequences (2).

IDENTIFICATION OF POTENTIALLY INAPPROPRIATE MEDICATIONS AND PRESCRIBING

Elderly patients carry a disproportionate share of the risk here, simply because comorbidities and polypharmacy are so common at that stage of life, which makes potentially inappropriate prescribing (PIP) a particular concern. The Beers and STOPP/START criteria are still the standard tools for catching PIP after the fact, but machine learning is increasingly being used to build predictive models that flag it before it happens — letting pharmacists and physicians step in with individualized interventions rather than reacting after the harm is already done. Gradient boosting classifiers paired with feature-screening methods have shown particularly high sensitivity for detecting inappropriate prescribing and prescribing omissions among elderly cardiovascular patients (2).

MEDICATION ERRORS IDENTIFICATION

The Food and Drug Administration receives over 100,000 reports of suspected medication errors from the United States each year, with prescription errors occurring at rates of 0.3-9.1% and dispensing errors at 1.6-2.1% in European hospitals. Comprehensive approaches to patient safety, including electronic prescription systems and barcode medication administration, can prevent up to 70.2% of medication-error-related harm. Commercial machine learning systems have been developed to detect overdose and underdose prescriptions with low false-positive rates, and unsupervised outlier-detection methods have achieved strong performance identifying abnormal prescriptions against real clinical datasets (2,16). Hybrid systems combining machine learning with rule-based expert systems have also been developed to predict medication errors at the level of the individual patient, while newborn-centered models have been used to detect errors across the full pharmacotherapy process, from prescription through administration and monitoring, in neonatal intensive care settings (2); one such system, validated specifically for precision screening of medication errors in a neonatal intensive care unit, reported meaningfully improved detection sensitivity relative to standard chart review (13).

ELECTRONIC HEALTH RECORD (EHR) INTEGRATION

EHR systems get more useful once predictive algorithms are layered on top — they can flag a prescribed drug that deviates from established patterns of appropriate use, essentially catching outliers before a human reviewer would. AI can also help with drug-selection decisions by identifying which patients are unlikely to have adverse effects from a given medication. Applying natural language processing to the unstructured, free-text parts of an EHR — medication histories, ADRs, pharmacokinetic consultations — has real potential to improve care and support real-time evaluation of medication efficacy, including feeding useful information to pharmacy and therapeutics committees (2). Beyond that, tighter AI-EHR integration generally makes pharmacy practice run smoother: pharmacists can review patient histories faster, track adherence patterns more easily, and lean on AI-powered chatbots to deliver personalised medication advice and reminders (1).

MEDICATION ADHERENCE AND THERAPY MANAGEMENT

MEDICATION ADHERENCE TECHNOLOGIES

Roughly half of patients living with chronic disease don't take their medications as prescribed, and the consequences aren't small — higher morbidity and mortality, plus an estimated US$100 billion in costs every year. The reasons behind non-adherence are messy and multifactorial, which is exactly why AI-enabled technologies have found a foothold here: electronic pillboxes and bags, electronic pill bottles, ingestible sensors, blister-pack technology, electronic medication management systems, patient self-report tools, video-based monitoring, and motion-sensor technology all represent different attempts to close that gap (2).
Medication event monitoring systems use a sensor embedded within the pill cap to record every occasion a patient opens their pill bottle, with newer devices transmitting adherence data wirelessly. Near-field communication tags embedded in smart blisters can detect when a tablet is removed, while ingestible sensors, co-encapsulated with the medication, transmit a signal once dissolved by gastric fluid. Motion-sensor technologies, including wearable accelerometers, can detect hand gestures associated with medication-taking behaviour, and video-based monitoring allows patients to self-record ingestion events for review by pharmacists or AI systems (2).

MEDICATION THERAPY MANAGEMENT (MTM)

AI-enabled MTM platforms combine population health analytics with telemedicine to identify and priorities at-risk patients and provide decision support for pharmacist-led interventions. In one evaluation of a comprehensive medication management programme combining population health data, telemedicine, and proprietary risk scoring, pharmacists working alongside AI systems achieved a statistically significant reduction in total cost of care, along with meaningful reductions in emergency department visits, hospital admissions, and bed-days (2). A retrospective observational study of a large Medicaid health plan reported comparable findings using regression-based methods to isolate the effect of an AI-supported medication management platform from broader cost and utilization trends, lending independent support to the claim that these platforms can generate measurable, non-trivial savings rather than only the projected savings typical of earlier, non-AI programme evaluations (11).

COMMUNITY PHARMACY, DISPENSING, AND TELEPHARMACY

AUTOMATED DISPENSING AND INVENTORY MANAGEMENT

Healthcare systems are transitioning from single hospital-based care towards collaborative, community-based models, and robotic dispensing systems — including automated dispensing robots and bar-coded dispensing support systems are helping community pharmacists preserve patient safety during this transition. Studies evaluating robotic dispensing systems have documented significant reductions in both preventable and unpreventable dispensing errors, alongside marked reductions in pharmacists' median dispensing time per prescription (2). A before-and-after study of a robotic original-pack dispensing system in a Spanish outpatient hospital pharmacy found a substantial reduction in the dispensing-error rate alongside a 59.3% reduction in daily staff time spent on stock intake, storage, and order selection, together with high staff satisfaction with the new system (17); a separate evaluation of a combined robotic and bar-coded dispensing platform in Japan reported similar safety and efficiency gains when the technology was paired with structured collaboration between pharmacists and support staff, suggesting the benefits depend as much on workflow redesign as on the technology itself (18).

AI-powered chatbots can simulate interactions between pharmacists and patients, resolving routine queries while routing complex questions to human staff. AI also supports inventory management by predicting future medication requirements from historical purchasing data; one European retailer achieved 95% forecasting accuracy using an AI-powered demand-prediction system, enabling reduced delivery lead times (2,3).

Automated dispensing systems have transformed hospital pharmacy workflows by delivering precision that substantially reduces human error; the University of California San Francisco Medical Center, for instance, has reported that its robotic dispensing technology prepared over three million medication doses, including oral, injectable, and chemotherapy preparations, without a single error, freeing pharmacists to focus on direct patient care (2,3).

TELEPHARMACY AND TELEHEALTH

Telehealth refers to the exchange of medical information between sites via electronic communication to improve health outcomes. Chatbots can speed up history-taking by using natural language processing to prompt patients with structured questions based on self-reported symptoms, including the detection of adverse drug events. In telehealth settings, automated phone calls to patients starting new medications have proven effective in identifying adverse drug events, with concerning responses triggering referral to a pharmacist for further assessment (2).

During the COVID-19 pandemic, one large Chinese hospital launched an AI-based internet hospital pharmacy service in which prescription rules were embedded into the online system to review prescriptions before pharmacist verification and dispensing. Medicine pick-up codes, generated as QR codes, allowed patients to collect fragile or specially stored medications from an offline pharmacy window, while other medications were delivered by courier and volunteer pharmacists provided free online consultations — illustrating a practical model for AI-supported pharmacy service delivery during a public health emergency (2).

PATIENT CARE AND PERSONALISED MEDICINE

AI is transforming patient care by enhancing diagnostic accuracy and enabling more precise, individualized treatment planning. AI-based tools, particularly in medical imaging and genomic analysis, have been shown to outperform traditional diagnostic methods in identifying diseases such as cancer and heart conditions, supporting clinicians in making better-informed decisions (1).

AI leverages patient-specific information, including genetic data, medical history, and lifestyle factors, to create individualized treatment plans that enhance therapeutic effectiveness while minimizing side effects, making it easier for patients to adhere to prescribed treatment; predictive models can additionally identify individuals at high risk of specific illnesses, enabling preventive interventions. The Google DeepMind Health project, for example, has helped clinicians at Moorfield's Eye Hospital review medical records rapidly to improve eye treatment, while IBM's Watson for Oncology has been used as a decision-support system analyzing patient data against historical cancer cases to help oncologists identify treatment options (1,3).

Virtual health assistants, such as the "Molly" application, guide patients through chronic condition management between physician visits, while smartphone applications such as Ai Cure use webcam monitoring to support adherence to complex regimens, particularly within clinical trial settings. Wearable devices and mobile health applications, ranging from consumer products such as Fitbit and Apple Watch to implanted devices such as pacemakers, allow providers to assess real-time physiological data that can inform medication schedules and broader care decisions (1,3). The genomic and molecular-level AI platforms that inform these personalized treatment plans — including the target-identification and compound-screening tools discussed in the companion review, "Artificial Intelligence in the Pharmaceutical Industry: Innovating Drug Discovery, Clinical Trials, and Supply Chains" — represent the upstream counterpart to the patient-facing personalization described here.

CHALLENGES TO SAFE AND EQUITABLE ADOPTION IN PRACTICE

DATA PRIVACY AND SECURITY

Concerns surrounding data privacy and security have arisen alongside the widespread deployment of AI-based healthcare applications, given that health information is inherently sensitive and a common target for data breaches. Patients may be concerned that large-scale collection and sharing of their data for AI training purposes will infringe upon their privacy, particularly where sufficient consent has not been obtained; the acquisition of DeepMind Health by Google in 2018 attracted scrutiny after it emerged that the UK National Health Service had shared the data of 1.6 million patients with DeepMind without adequate patient consent (2).

ALGORITHMIC BIAS

Biases present within training datasets can lead to biased outputs, with minority populations often under-represented, resulting in lower predictive performance for these groups. Even accurate, representative data can produce problems if it reflects pre-existing biases within the healthcare system itself; because African-American patients have historically received less opioid analgesia on average than white patients, a system trained on such records may learn to recommend systematically lower doses to African-American patients, despite this pattern reflecting systemic bias rather than genuine biological difference (2).

INTEROPERABILITY AND TRUST

Integrating AI systems with existing clinical and pharmacy infrastructure is complicated by variation in system architecture and data formats, which can disrupt established workflows. Many AI models function as opaque "black boxes," making it difficult to interpret how a given recommendation was reached, which can erode trust among clinicians, pharmacists, and patients (1,2).

WORKFORCE READINESS AND SOCIAL FACTORS

One of the most persistent social concerns surrounding AI in healthcare is the fear that automation will displace jobs, a belief that, although largely based on a misunderstanding of AI's current narrow capabilities, continues to generate distrust of AI-based interventions in clinical practice. Building genuine trust and acceptance among clinicians and patients remains a critical prerequisite for successful adoption, alongside concerns regarding potential impacts on the clinician-patient relationship and the risk of skill attrition among practitioners who come to rely excessively on automated recommendations (1,3).

Healthcare professionals have historically been slower than other industries to incorporate new technologies into daily practice, and the implementation period represents a particularly critical stage in the broader innovation process. Comprehensive education and training programmes focused specifically on AI literacy are therefore essential to equip pharmacists with the skills required to use these tools effectively and to understand both their capabilities and their limitations (2). A recent survey-based study of practising pharmacists similarly found that concerns about AI implementation centre on inadequate training, workflow disruption, and uncertainty about system reliability, even where pharmacists are broadly optimistic about the efficiency gains AI can offer — underscoring that technical capability alone will not secure safe adoption without parallel investment in workforce preparation (6). A separate national survey of United States pharmacists reported a comparable pattern: most respondents supported AI's use provided existing patient-safety protocols were preserved, and many indicated a willingness to pursue further training, but also called for pharmacists to be treated as key stakeholders in how AI tools are designed and deployed rather than simply asked to adopt finished systems (9). Preliminary survey findings among pharmacy trainees point in a similar direction even earlier in the pipeline: students and early-career practitioners report broadly positive attitudes toward AI but consistently identify a lack of structured curricular exposure as the main barrier to confident use (19).

FUTURE DIRECTIONS

- Deeper EHR integration: enabling pharmacists to review patient histories more efficiently, monitor adherence patterns, and identify emerging health risks, supported by AI-powered chatbots delivering personalized medication advice and education (1).
- Advancing automated dispensing: improving accuracy and system optimization of dispensing robots through machine learning, enabling predictive maintenance, patient-specific customization, and automated cross-referencing of dispensed medications against patient records to flag interactions or allergies (1).
- Public health monitoring and equity: analyzing large-scale health data to detect emerging trends in disease and medication usage, while identifying demographic and socioeconomic disparities to support tailored initiatives for underserved populations (1).
- Professional development and "pharmacointelligence": embedding AI literacy and ethics training within pharmacy curricula and continuing education, and demystifying AI concepts for practicing pharmacists, to ensure the profession is prepared to lead, rather than simply respond to, this transformation of care (1,2,4).
- Professional guidance and standard-setting: national pharmacy bodies have begun issuing formal AI guidance for the profession; the Royal Pharmaceutical Society, for example, has published a policy supporting the responsible and effective use of AI in pharmacy practice, explicitly identifying workforce education and skills investment as a priority alongside patient safety (7).
- Forecasting near-term clinical impact: a 2025 forecasting exercise conducted by the American College of Clinical Pharmacy modelled which AI applications are likely to reach routine use across the medication-use process and the Pharmacists' Patient Care Process within the next several years, offering a practical roadmap against which the developments discussed in this review can be tracked (10).

LIMITATIONS OF THIS REVIEW

This review synthesizes existing secondary literature rather than reporting a systematic, protocol-driven search, and no formal quality appraisal was applied to the sources cited. Several of the practice-level benefits described here — reduced dispensing errors, improved adherence, cost savings from AI-enabled MTM — are drawn from single-institution case studies or vendor-reported outcomes rather than multi-site randomized evaluations, and the true generalizability of these figures to other health systems is uncertain. The evidence base on pharmacist and patient trust in AI is also still forming: the survey literature cited in Section 6.4 captures attitudes at a single point in a rapidly changing technological and regulatory landscape, and pharmacists' willingness to adopt AI tools may shift considerably as the tools themselves, and the guidance governing them, continue to evolve.

CONCLUSION

Artificial intelligence has, at this point, become an ordinary part of pharmacy practice rather than a novelty showing up across clinical decision-making, medication safety, adherence, dispensing, and direct patient engagement. What the evidence gathered here shows is that these tools can meaningfully cut medication errors, sharpen the precision of high-risk dosing, strengthen adherence among patients managing chronic disease, and give pharmacists back time for direct patient care instead of repetitive administrative work (2,3).

Whether that adds up to safe and equitable adoption everywhere, though, is a different question, and not one this review can answer with certainty. Data privacy, algorithmic bias, poor interoperability, opaque decision-making, workforce readiness — none of these problems go away on their own; they need sustained investment in AI literacy, validation, and trust-building between pharmacists, patients, and the people building the technology. Embedding AI education into pharmacy training, and treating "pharmacointelligence" as a deliberate integration of AI into patient-centered practice rather than something that simply happens to the profession, will matter a great deal to whether pharmacists end up leading this transformation of care or just keeping pace with it (1,2).

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HOW TO CITE: Nisha Fangal, Lavanya Sawarkar, Prashant Chaturvedi, Srushti Tribhuvan, Yogesh Wankhede, Artificial Intelligence in Clinical and Community Pharmacy Practice: Transforming Medication Safety and Patient Care, Int. J. of Pharm. Sci., 2026, Vol 4, Issue 9, 3222-3232, https://doi.org/10.5281/zenodo.22953585