

Health Information Systems for Medication Safety in Primary Care: From Clinical Decision Support to Connected Devices*

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Abstract

Medication errors and adverse drug events are a leading and largely preventable threat to patient safety and a substantial burden on health systems, and most prescribing, dispensing, and long term medication management now take place in primary and ambulatory care. This narrative review examines how health information systems and communication technologies, the digital tools, connected devices, and data practices that capture, share, and act on medication information, support medication safety in primary care. Drawing on full text studies from a PubMed search covering 2021 to 2026 and focused on primary and ambulatory settings, it describes converging approaches: clinical decision support and prescribing analytics, electronic records and routinely collected data for pharmacovigilance, patient facing portals and applications, connected devices and remote monitoring for error prevention, and digital support for medication reconciliation across care transitions. Benefit depends less on the technology than on interoperability, integration into clinical workflow, the engagement of clinicians and patients, and whether interventions are sustained. Polypharmacy and high-risk prescribing recur as priority targets, with antimicrobial stewardship as one illustrative example rather than the review's central concern. Drivers and barriers, a protocol-heavy evidence base, interoperability and equity, and implications for information systems and public health are discussed.

Keywords: health information systems; medication safety; primary care; clinical decision support; Internet of Things; interoperability; error prevention

Introduction

Medication errors and the adverse drug events they cause are among the most common and largely preventable threats to patient safety. A distinction matters: many adverse drug events follow from errors and are avoidable, whereas type B reactions are idiosyncratic and occur unpredictably, so the tools discussed here target the preventable, error related share of harm. They occur at every step of the medication process, from prescribing and dispensing to monitoring and patient self-management and carry a substantial human and economic cost; the World Health Organization has estimated the global cost of medication errors at around US\$42 billion a year (Eshraghi et al., 2025). The burden is no longer concentrated in hospitals: most medicines are prescribed, supplied, and managed over long periods in primary and ambulatory care, yet medication errors in these settings have been studied far less than those in inpatient care (Naserallallah et al., 2023). As populations age and live with multiple chronic conditions, the volume and complexity of community prescribing continue to grow, and with them the opportunities for harm.

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Health information systems have become central to how primary care responds to this challenge. The term information management here covers the digital tools, connected devices, and data practices that capture, share, and act on medication information, including electronic health records, clinical decision support, prescribing dashboards, patient portals, mobile applications, connected devices, and the routine datasets used for surveillance and research. These tools promise safer prescribing, earlier detection of problems, and better continuity of care. They speak to the World Health Organization Medication Without Harm initiative, whose goal of halving severe avoidable medication related harm continues to frame prescribing safety research in general practice (McCarthy et al., 2025). Whether they deliver in everyday practice is a separate question, with clear public health stakes. Against this background, the objectives of this review are threefold: to map the types of health information systems and communication technologies applied to medication safety in primary and ambulatory care between 2021 and 2026; to synthesise what the recent evidence shows about their effects, their limits and the conditions under which they are adopted, connected, and sustained; and to draw out the implications for information systems design and for public health. It is organised around the main classes of tool that emerged, from decision support at prescribing to connected devices in the patient's home.

Methods

This is a narrative review conducted with a structured, reproducible search. A narrative rather than systematic or scoping review was chosen deliberately: the aim was to map and interpret a heterogeneous body of tools, data practices, and study designs and to draw out cross-cutting themes for information systems practice, rather than to answer a single narrow question or pool effect estimates, for which the diversity of interventions and outcomes was unsuited. PubMed was the single bibliographic database searched, on 29 May 2026. The search combined three concept blocks with the Boolean operator AND, each block joining controlled vocabulary (MeSH) with free-text title and abstract terms by OR. Block one captured medication safety, anchored on MeSH headings such as «Medication Errors», «Drug-Related Side Effects and Adverse Reactions», «Patient Safety», «Inappropriate Prescribing», and «Medication Reconciliation». Block two captured information systems and digital methods, anchored on «Medical Informatics», «Decision Support Systems, Clinical», «Electronic Health Records», «Medical Order Entry Systems», «Artificial Intelligence», «Machine Learning», «Data Mining», and «Telemedicine». Block three captured the primary and ambulatory setting, anchored on «Primary Health Care», «Ambulatory Care», and «General Practice». Each block also joined the corresponding free-text title and abstract terms by OR; the complete Boolean search strategy, reproduced verbatim, is given in the Appendix. The search identified 345 records. The 2021 to 2026 window reduced these to 137, and an English language limit left 136 for screening. After title, abstract, and full text screening against the criteria set out below, 62 studies met the review's focus on information management for medication safety in primary care and form its evidence base. Screening and selection were carried out by four reviewers working independently. Studies were included if they concerned a primary or ambulatory care setting, addressed an information system or communication technology applied to medication safety, were published between 2021 and 2026, and were available in English. Studies were excluded if they were confined to inpatient or hospital only settings, did not involve an information or digital tool, addressed medication topics unrelated to safety, fell outside the publication window, or were not available in full text. Disagreements were first resolved through discussion until consensus was reached, and any that remained were settled by a third reviewer. To limit selection bias, the criteria were fixed in advance, each item was assessed by more than one reviewer, and reasons for exclusion were recorded. The narrative synthesis then proceeded by reading each included full text, coding it by the type of information tool or data practice it described, grouping the studies into the categories used in the sections below, and comparing findings within and across categories to surface recurring enablers and barriers; a representative subset is cited to illustrate each approach rather than to catalogue every paper.

Two features of the evidence shaped this reading. First, a substantial share of the included studies, among them several of the strongest designs, are protocols for trials not yet reporting outcomes, so these are described as planned rather than proven. Second, some included studies sit at the boundary with hospital discharge, specialist outpatient clinics, or population databases; these were kept in view because medication safety in primary care depends heavily on these interfaces, and the setting is named where it is not general practice. As a narrative review the synthesis is interpretive, rests on a single bibliographic database, and involved no formal risk of bias appraisal; these are limitations, not claims of exhaustive coverage.

Supporting Safe Prescribing

Clinical decision support systems are the most studied component. Lampe et al. (2024), in a systematic review of decision support in primary and long term care, found these systems increasingly embedded in prescribing, but

the outcomes used to judge them heterogeneous, which makes their real effect hard to summarise. In paediatric prescribing, computerised physician order entry with decision support can reduce dose errors, although the strength of evidence varies (Ruutinen et al., 2024).

Trials in older adults give a more concrete picture. Jungo et al. (2023), in the OPTICA trial, built a medication review around an electronic decision support tool for general practitioners caring for older patients with multimorbidity and polypharmacy, testing its effect on the appropriateness of medicines. A multiarm trial in French general practice paired decision support with audit based feedback to reduce inappropriate antibiotic prescribing (Jeanmougin et al., 2024). Beyond alerts at the moment of prescribing, primary care increasingly uses tools that show prescribing patterns over time. McCarthy et al. (2025), in a systematic review of interactive dashboards giving general practices visual, longitudinal feedback on prescribing, found such tools can shift prescribing behaviour, although their design and target outcomes differ widely. Digital audit and feedback can reach clinicians at scale: in a national programme comparing digital and postal feedback to reduce inappropriate gabapentinoid prescribing, Andrade et al. (2022) found the digital arm achieved a mean reduction of about 11 percent.

One digital platform automated the analysis of outpatient prescriptions to monitor prescribing patterns and antimicrobial use in place of slow manual review (Kankanala et al., 2025). Stewardship at the boundary with hospital care also matters, since patients return to the community on these prescriptions, and a stepped wedge trial tested whether discharge focused audit and feedback reduces antibiotic overuse at that transition (Livorsi et al., 2025). A health information system based trial in China is testing automated, privacy preserving feedback to reduce unnecessary antibiotic prescribing (Chang et al., 2022).

Records, Data and Patient Engagement

Routinely collected primary care data are a resource for medication safety as well as a record of care. Databases derived from electronic health records support pharmacoepidemiology and pharmacovigilance, although missing prescription information can bias the conclusions drawn from them (Okoli et al., 2021). An observational study using United Kingdom records quantified how often older adults receive a medication review and how prescribing changes afterwards (Joseph et al., 2023), while another examined ethnic differences in guideline indicated statin initiation across more than a decade, with direct equity implications (Eastwood et al., 2021). Databases also reveal harms hard to capture in trials: a simulation using United Kingdom Biobank records separated the risk of anticholinergic burden from that of polypharmacy itself (Mur et al., 2025), and a review set out how national datasets can guide pharmacotherapy in people with dementia and late life mental disorders typically excluded from trials (Sondh et al., 2025). Where structured codes are too blunt, natural language processing can read clinical text: Gaspar et al. (2025) used such methods to detect bleeding events linked to antithrombotic therapy in discharge summaries more sensitively than diagnostic codes alone, a signal that matters for safe community follow up. Information management is not only a matter for clinicians. Assiri (2022), in a narrative review, concluded that patient access to electronic health records can improve medication management safety, though the evidence is uneven. National personal health records have been proposed to carry medication information across settings, and an observational study compared medicines listed in a national record with a pharmacist obtained history, finding gaps that matter for safety (Francis et al., 2024). A portal based intervention for busy primary care clinics monitored self reported adherence problems among older adults with polypharmacy and offered tailored support (Pack et al., 2025). A twelve month randomised trial found that a smartphone application could improve medication adherence in people taking several medicines (Li et al., 2021). Uptake depended on fit to daily life as much as on the software itself.

Connected Devices and the Internet of Things

A growing share of medication safety now depends on connected devices that sit between the clinic and the patient's home. The clearest example is the electronic, or smart, pillbox: a networked dispenser that records whether doses are taken and flags discrepancies after discharge. Shahani et al. (2022) tested such a device to reduce medication discrepancies and improve adherence, and reported candidly on how difficult these devices are to implement and sustain in routine care. Consumer smartphones play a similar role as low cost reminder nodes, as in the twelve month application trial reported by Li et al. (2021). In Internet of Things terms, both are edge devices that generate medication data outside the consultation. Communication technologies determine whether that data becomes useful. Remote monitoring and telemedicine extend prescribing and review beyond the visit, but their safety value depends on connecting device signals to clinical decision making rather than leaving them

in standalone apps. Wiwatkunupakarn et al. (2023) noted that clinical decision support and telemedicine are still studied separately even though they increasingly operate together, the integration an Internet of Things framework is meant to provide. For medication safety the target is error prevention: alerts and reconciliation triggered automatically when device or pharmacy data indicate a missed dose, a duplicate, or an interaction. The binding constraint is interoperability. Connected devices, portals, and records improve safety only when their data flow into a shared information system and reach the prescriber within the workflow; without that exchange they fragment care rather than coordinate it (Okoli et al., 2021; Hattingh et al., 2024). Across these studies, the device is the easy part; the information system architecture, communication standards, and human routines around them decide whether connected technology prevents error or adds noise.

High-risk Prescribing and Care Transitions

Transitions between hospital and community are a well known point of medication risk, and several information tools target this gap. Beyond the electronic pillbox discussed above (Shahani et al., 2022), a digital platform that shares medication records between hospitals and primary health clinics was evaluated for its effect on unintentional medication discrepancies at the first visit after discharge (Phang et al., 2025). Reliable handover of medicine information is the connecting theme. The OPTMED-D protocol describes a multifaceted intervention to prompt general practitioners and community pharmacists about patients in transition, since existing digital systems transfer information passively and rarely alert clinicians (Hattingh et al., 2024, protocol, outcomes not yet reported).

Polypharmacy is where information management and medication safety meet most directly in primary care. In the German AdAM trial, Brünn et al. (2024) evaluated a digital medication management application for patients with polypharmacy across primary care practices. Work from the same programme showed why outcomes depend on context: physicians' beliefs about an innovation help explain whether it is adopted (Söling et al., 2023), and patients integrate medication review and digital decision support into their lives in ways designers should anticipate (Brünn et al., 2021). Payne et al. (2025), in the IMPPP cluster randomised trial, combined general practitioner and pharmacist collaboration with informatics and clinician engagement to improve polypharmacy management.

Deprescribing is a frequent target, but here the evidence is still mostly planned rather than reported. A cluster trial protocol addresses inappropriate use of medicines for overactive bladder in older people in general practice (Soerensen et al., 2024), while regional dispensing data have tracked real change in proton pump inhibitor prescribing and deprescribing over time (Gendre et al., 2022). The information layer of deprescribing lies in explicit criteria built into decision support, and a Delphi study developed such definitions for antidiabetic drugs (Gerard et al., 2025).

Dispensing and prescribing are the points at which most preventable medication errors arise, and information tools target both. Naserallah et al. (2023) confirmed in a systematic review that medication errors are common in outpatient and ambulatory settings and interventions to reduce them still poorly characterised. Reviewing community pharmacy dispensing errors, Eshraghi et al. (2025) reported a median dispensing error rate near 1.4 percent and reductions of up to about 98 percent where automated dispensing systems were introduced, pointing to technology and workflow redesign as the most effective responses. Antimicrobial prescribing is one prominent example within this broader problem, valuable because it links individual medication safety to the public health problem of resistance rather than because it is central to this review; a cluster randomised trial, for instance, tested a bundle of education, a decision support algorithm, deferred prescriptions, and feedback to reduce inappropriate antibiotic use for respiratory infections in outpatients (Butt et al., 2025). These tools work best when paired with clear clinical rules and attention to professional behaviour.

Equity and Population Health

Information management can widen or narrow inequalities. Digital delivery can reach an entire system at once, as the national scale audit and feedback intervention above illustrates (Andrade et al., 2022). A case study of regional, centralised prescription review described digital pharmaceutical governance as a means to reduce health inequality (Jia et al., 2026), and the analysis of statin initiation across ethnic groups made visible a gap that routine data can both reveal and help close (Eastwood et al., 2021).

Two further points weigh here. First, routinely collected data let whole registered populations be monitored for unsafe prescribing rather than relying on case by case detection, turning medication safety into a measurable public health indicator (Joseph et al., 2023; Okoli et al., 2021). Second, tools that assume reliable connectivity, digital literacy, or a personal smartphone risk leaving behind the older, poorer, and more isolated patients who carry the heaviest medication burden, so equitable access must be planned rather than assumed. Newer tools raise the same double edged question. Trigger tools adapted for primary care can help detect adverse events recorded in the medical record, extending a hospital method into the community (Dhamanti et al., 2025), and Holderried et al. (2026) tested generative artificial intelligence for patient centred discharge letters, although the measured outcome was comprehension rather than safety. Their public health value will depend on whether they reach those most exposed to medication harm.

Synthesis and Outlook

Read together, these studies show a consistent pattern: the information tools that support medication safety in primary care are varied, but their success rarely turns on the sophistication of the technology. Several conditions recur. Interoperability and shared data standards determine whether device, pharmacy, and record data reach the prescriber as a coherent picture or stay trapped in separate systems (Okoli et al., 2021; Hattingh et al., 2024), and standardisation of terminology and interfaces is what lets a tool built in one setting be reused in another. Integration into clinical workflow decides whether a tool supports a decision as it is made or becomes an interruption that clinicians learn to bypass, while usability governs whether patients and professionals adopt it at all. Data quality is a precondition throughout, since missing or inconsistent prescription information biases both point of care alerts and the population surveillance built on the same records. Implementation barriers such as competing demands on clinician time and uneven digital infrastructure explain many muted effects; user trust, particularly in automated alerts and generative tools, decides whether their output is acted on or dismissed as noise; and interventions that build feedback loops, returning audit, dashboard, or device data in an actionable form, are the ones most likely to change behaviour and to sustain the change. The most convincing results come from combinations of tools that fit a particular setting rather than from any single product.

Two cautions follow. A large share of the strongest designs are still protocols, so the field is rich in planned trials and poor in completed outcome data, and conclusions should be read in that light. Polypharmacy and high-risk prescribing stand out as priorities where information management already has a credible role and the public health return is clearest; antimicrobial stewardship is one visible instance of this pattern rather than the review's main subject.

Several priorities follow. The most pressing is to close the gap between planned trials and reported outcomes; the field needs completed effectiveness trials with patient relevant endpoints. Comparative work is needed, since the strongest results came from combinations of tools, yet few studies test one configuration against another. Implementation and sustainment deserve as much attention as efficacy, given how often benefit faded once initial support was withdrawn. Evaluations should report effects by social group so that equity is measured rather than assumed, emerging tools such as natural language processing and generative artificial intelligence need prospective validation against safety outcomes, and routinely collected primary care data should be developed as a standing surveillance resource at population scale.

Conclusion

Information management has moved to the centre of medication safety in primary care. Electronic records, decision support, prescribing analytics, patient facing tools, and shared data each contribute, and routinely collected data add a public health dimension by letting whole populations be monitored for unsafe prescribing. The recurring message is practical rather than technological: the question is no longer whether to adopt these tools but how to embed and sustain them so that they reach those most at risk. For managers and policymakers, investment should favour integration into workflow, training, and maintenance rather than tools alone, with routine monitoring of medication safety as a measure of health-system performance. Closing the gap between planned trials and demonstrated outcomes is the next task for research, and a fair distribution of benefit is the test that matters most for public health.

Appendix A: Scopus search strings

PubMed search executed on 29 May 2026. The three concept blocks were combined with AND; terms within each block were combined with OR. Field tags: [Mesh] for Medical Subject Headings, [tiab] for title and abstract. The date and language limits reported in the Methods were applied to this strategy.

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(  
"Medication Errors"[Mesh] OR "Drug-Related Side Effects and Adverse Reactions"[Mesh]  
OR "Patient Safety"[Mesh] OR "Inappropriate Prescribing"[Mesh] OR "Medication Reconciliation"[Mesh]  
OR "medication error"[tiab] OR "medication errors"[tiab] OR "medication safety"[tiab]  
OR "prescribing error"[tiab] OR "prescribing errors"[tiab]  
OR "adverse drug event"[tiab] OR "adverse drug events"[tiab]  
OR "adverse drug reaction"[tiab] OR "adverse drug reactions"[tiab]  
OR "drug-related problem"[tiab] OR "drug-related problems"[tiab]  
OR "inappropriate prescribing"[tiab] OR "medication reconciliation"[tiab]  
OR pharmacovigilance[tiab] OR polypharmacy[tiab]  
)
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AND

```
(  
"Medical Informatics"[Mesh] OR "Decision Support Systems, Clinical"[Mesh]  
OR "Electronic Health Records"[Mesh] OR "Medical Order Entry Systems"[Mesh]  
OR "Artificial Intelligence"[Mesh] OR "Machine Learning"[Mesh] OR "Data Mining"[Mesh]  
OR "Telemedicine"[Mesh]  
OR digital[tiab] OR "data-driven"[tiab]  
OR "electronic health record"[tiab] OR "electronic health records"[tiab] OR EHR[tiab]  
OR "clinical decision support"[tiab] OR CDSS[tiab]  
OR "computerized physician order entry"[tiab] OR CPOE[tiab]  
OR "electronic prescribing"[tiab] OR e-prescribing[tiab]  
OR "machine learning"[tiab] OR "artificial intelligence"[tiab] OR "deep learning"[tiab]  
OR "predictive model"[tiab] OR "predictive models"[tiab]  
OR "data mining"[tiab] OR "health information technology"[tiab]  
OR informatics[tiab] OR algorithm[tiab] OR algorithms[tiab]  
)
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AND

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(  
"Primary Health Care"[Mesh] OR "Ambulatory Care"[Mesh] OR "General Practice"[Mesh]  
OR "primary care"[tiab] OR "primary health care"[tiab]  
OR "general practice"[tiab] OR "family practice"[tiab] OR "family medicine"[tiab]  
OR "ambulatory care"[tiab] OR outpatient[tiab] OR outpatients[tiab]  
OR "general practitioner"[tiab] OR "general practitioners"[tiab]  
)
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