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Smart Pharmacies in Geriatric Care: An IoT Framework for Medication Adherence and Polypharmacy Management*

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Abstract

Older adults visit community pharmacies more regularly than virtually any other part of the healthcare system, which places these settings in a natural position to support polypharmacy management. The Internet of Things (IoT) opens a realistic path to turning pharmacies into active, data-generating nodes within geriatric care networks, yet no integrated framework has so far mapped what this would look like in practice. Based on a systematic literature search covering 74 peer-reviewed studies (January 2020-January 2026; PubMed, Scopus, Web of Science; 30 countries), supplemented by a targeted search on IoT frameworks and geriatric care, this narrative review proposes a four-layer conceptual framework for IoT-based geriatric medication management. The framework covers sensing and capture, local clinical decision support, network integration, and patient engagement; applied to older adults, it supports polypharmacy reconciliation, opportunistic point-of-care screening, and chronic disease adherence monitoring. Three barriers persist: interoperability gaps, limited digital literacy among pharmacists and patients, and unequal access to digital infrastructure. Realising the pharmacy's potential as an IoT-enabled care node requires enforced interoperability standards, sustained investment in pharmacist digital training, and deployment strategies that explicitly protect those most at risk of digital exclusion.

Keywords: Internet of Things; community pharmacy; geriatric care; polypharmacy; medication adherence; digital health; IoT framework; error prevention

Introduction

Community pharmacies sit at an unusual intersection in local healthcare systems. No appointment is required, opening hours are long, and for many older adults, particularly those who live alone or have mobility limitations, the local pharmacy is visited far more often than a general practitioner. This accessibility matters increasingly as populations age. Adults over 65 carry a disproportionate and growing burden of multimorbidity and polypharmacy, with concurrent use of five or more prescription medications now common rather than exceptional. That volume of medication brings real clinical risk: drug-drug interactions, adverse reactions, and adherence failure. These risks compound when cognitive decline, reduced health literacy, or social isolation are present, and all three are prevalent in older populations, yet often invisible to clinicians working within appointment-based, episodic care models. For most of their history, pharmacies have been dispensing sites, important in their role but largely passive. Structural integration with primary care networks has been limited, and there has been no real mechanism for monitoring patients continuously between prescription encounters. Digital technologies are beginning to change that. Electronic prescribing, clinical decision support tools, telepharmacy, mobile health applications, and point-of-care diagnostic devices are each extending what a community pharmacy can offer (Pargaien et al., 2022; Shah et al., 2026). But what remains poorly examined is how these tools might be brought together into something coherent: a framework capable of addressing the specific, compounding clinical

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challenges of older patients managing multiple medications. The Internet of Things deserves particular attention in this context. IoT refers broadly to networked, sensor-equipped devices that generate real-time data streams tied to individual patients and usable within clinical workflows. In healthcare, that includes automated dispensing systems, wearable monitors, point-of-care diagnostic hardware, and smart medication management tools (Kumari et al., 2025; Shah et al., 2026).

A systematic review of IoT and Internet of Medical Things (IoMT) developments between 2011 and 2024 found strong evidence of improvements in operational efficiency and care quality through automation and real-time data access, while also identifying data privacy, interoperability, and cybersecurity as governance challenges that cannot be left for later (Shah et al., 2026).

Existing literature tends to treat individual IoT technologies in isolation, within a single clinical domain, a single technology type, or a specific regional setting, without asking how these components might work together within community pharmacy to support older patients. A systematic search of the peer-reviewed literature on digital technologies in retail and community pharmacy, encompassing 74 studies from 30 countries published between 2020 and 2026, confirmed both the breadth of digital pharmacy innovation and a notable gap: no unifying framework exists that integrates IoT components specifically for geriatric care. Earlier narrative reviews have acknowledged the transformative potential of IoT in pharmacy but have stopped short of proposing a workable architecture for older adult populations (Pargaien et al., 2022). Evidence on IoT-enabled adherence has shown consistently positive effects in older patients with chronic conditions (Ghozali, 2023), yet these findings have not been connected to the structural context of pharmacy as a node within a geriatric care system. This review addresses that gap directly. Drawing on a systematic search of the peer-reviewed digital pharmacy literature, supplemented by a targeted Scopus search on IoT frameworks and geriatric applications, a four-layer IoT framework for the community pharmacy as a geriatric care node is proposed and developed. The framework is grounded in documented evidence and designed to be practically useful for health system planners, pharmacy practitioners, and digital health researchers. Three clinical use cases illustrate how the framework translates into real scenarios in geriatric medication management.

Methods

Evidence for this review was identified through a systematic search of PubMed, Scopus, and Web of Science, covering peer-reviewed publications on digital technologies in retail and community pharmacy from January 2020 to January 2026. From an initial yield of 1,949 records, 18 duplicates were removed, leaving 1,931 references for title and abstract screening. A total of 74 studies were confirmed for inclusion following two-stage screening. Included studies originated from 30 countries across six continents and covered a wide range of study designs, including randomised trials, qualitative studies, systematic reviews, cross-sectional surveys, and observational research.

Ten of the 74 included studies were selected as primary sources on the basis of their direct relevance to IoT-applicable technologies, geriatric patient populations, medication safety outcomes, or care network integration. Selection followed thematic proximity to the core research questions rather than formal quality appraisal, consistent with narrative review methodology.

A supplementary literature search was conducted in Scopus in June 2026 to extend coverage of IoT-specific frameworks and geriatric care applications. Search strings covered IoT frameworks in healthcare, IoT-based medication adherence in older adults, ambient assisted living technologies, smart medication management devices, and interoperability standards including HL7 FHIR. Results were restricted to English-language articles and reviews published after January 2019. Literature focused primarily on cybersecurity architectures, intrusion detection, federated learning, or blockchain without a clinical dimension was excluded. After title, abstract, and full-text screening, nine additional sources were incorporated into the synthesis; a further six were retained for specific subsections covering barriers, equity, and broader patient outcomes. Framework development followed iterative narrative synthesis across the full evidence base. Evidence was organised thematically by technology type and function, then mapped onto a four-layer architecture grounded in IoT system design principles as described in the reviewed literature. Consistent with narrative review methodology, no formal risk-of-bias assessment was performed. The conceptual nature of the framework and the absence of primary data collection are acknowledged as limitations throughout.

Results

Evidence for IoT-Enabled Geriatric Pharmacy

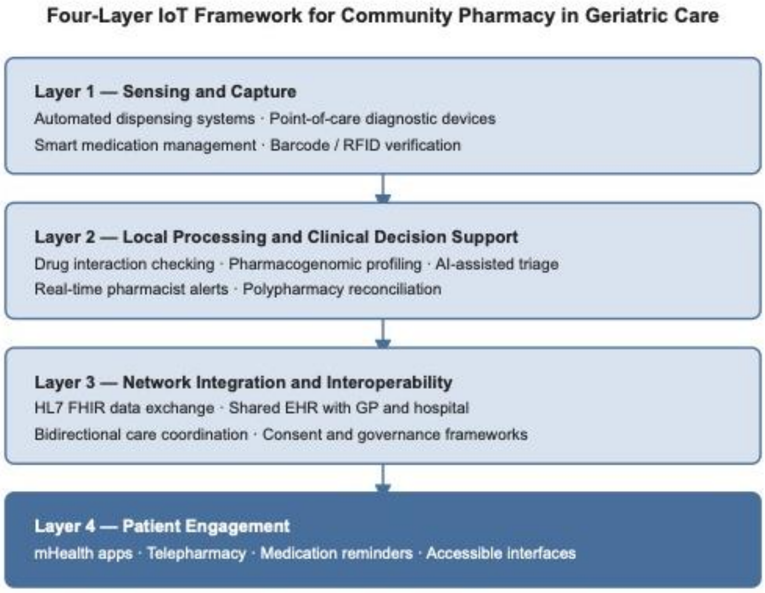
The reviewed evidence consistently supports the clinical potential of digital community pharmacy for older adults, though it also reveals how fragmented that development has been. The literature search identified eight active technology clusters across retail and community pharmacy settings. Of these, automated dispensing, point-of-care testing, clinical decision support, EHR integration, and mobile health applications are the most directly relevant to IoT-enabled geriatric care. A parallel trajectory is evident in wearable monitoring, smart medication management devices, and standards-based data integration frameworks, with growing uptake in older adult populations specifically (Shah et al., 2026; Ghozali, 2023; Kumari et al., 2025). Medication adherence is the most consistently reported benefit across the reviewed literature. A systematic review of 33 IoT studies found robust evidence of adherence improvement in older patients managing chronic conditions, with real-time monitoring, automated reminders, and personalised feedback as the most effective components (Ghozali, 2023). A real-world evaluation of a diabetes remote monitoring programme found that participants showed meaningfully higher adherence than non-participants, with adherence gains increasing proportionally with longer programme engagement (Munshi et al., 2021).

The safety evidence is equally strong. A six-year analysis of dispensing errors in Finnish community pharmacies recorded a fall from 3,913 reported errors in 2015 to 2,117 in 2020 (a relative risk of 0.54), with the sharpest decline following national rollout of a Medicines Verification System (Mäkinen et al., 2024). In Belgium, a clinical decision support system deployed across 490 pharmacies achieved 80% active adoption and produced measurable improvements in folic acid co-prescription with methotrexate (from 75.8% to 79.8% over four years) and gastroprotection rates in high-risk NSAID users (Bogaerts et al., 2024). The PREPARE pharmacogenomics trial, spanning 18 hospitals, nine community health centres, and 28 pharmacies across seven European countries, showed that genotype-guided prescribing cut clinically relevant adverse drug reactions from 27.7% to 21.0% in patients with actionable drug-gene variants, corresponding to an odds ratio of 0.70 (95% CI 0.54–0.91) and a 30% relative reduction across the full study population (Swen et al., 2023). Point-of-care diagnostics show particular promise for reaching older adults with undiagnosed conditions. A French study using a single-lead ECG device across 54 pharmacies in four municipalities detected previously undiagnosed atrial fibrillation in 1.26% of screened individuals aged 65 and above. Overall screening uptake was 17.2% of the eligible community population, reaching 25.7% in the 70–74 age group (Olindo et al., 2022). These numbers illustrate something important: pharmacy-embedded IoT diagnostic devices can operate as population-level screening infrastructure precisely because they require no appointment.

EHR interoperability between pharmacy, general practice, and hospital systems is the single most consistently documented prerequisite for realising the value of digital pharmacy technologies. A mixed-methods evaluation across 35 community pharmacies and 31 GP practices in England found that 69% of active system users reported improved patient care delivery and 54% noted better clinical decision-making, yet only 37% of enrolled pharmacies were actively using the shared system. The main barrier was the obligation to duplicate entries across multiple mandated platforms (Fynn et al., 2026). The USFarmácia programme in Portugal demonstrated what working connectivity can achieve: structured pharmacy-primary care data exchange, combined with bundled payment incentives, produced measurable population-level improvements in blood pressure and lipid control (Costa et al., 2023).

A Four-Layer IoT Framework for Geriatric Community Pharmacy

Drawing on the synthesised evidence, a four-layer conceptual framework is proposed for the integration of IoT technologies in community pharmacy for geriatric medication management. The framework is modular, allowing phased implementation, and explicitly acknowledges the equity and digital literacy constraints documented in the reviewed literature as design constraints rather than residual problems.



Layer 1: Sensing and Capture

Source: own

Layer 1 covers the physical devices and data collection mechanisms in or connected to the community pharmacy. This includes automated dispensing systems generating longitudinal dispensing logs, point-of-care diagnostic devices capturing biomarker and vital sign data, smart medication management systems with intake verification, and barcode or RFID systems for medication checking. Multi-agent distributed system simulation has demonstrated that Layer 1 IoT infrastructure is operationally feasible and financially viable in a major pharmacy chain context (Basingab, 2020). For older adults specifically, smart medication management devices incorporating biometric authentication, adaptive scheduling based on individual adherence patterns, and real-time caregiver alerts represent a clinically mature application, particularly relevant for patients with Alzheimer's disease or other cognitive impairments (Kapse et al., 2025). The broader technical feasibility of real-time physiological monitoring outside clinical environments has also been established (Nuraeni et al., 2025).

Layer 2: Local Processing and Clinical Decision Support

Layer 2 is where raw sensor data becomes clinically actionable. Pharmacy-based software or edge computing infrastructure processes incoming data streams against clinical rules, pharmacogenomic profiles, drug interaction databases, and individual medication records, generating structured alerts for the pharmacist. The evidence base for this layer is strong. It encompasses drug-disease interaction checking and gastroprotection in high-risk older patients (Bogaerts et al., 2024), and AI-assisted triage for identifying patients who need GP referral from a minor ailment service, achieving a classification accuracy of 0.934 in a study drawing on data from over 14,000 patients in Spanish community pharmacies (Amador-Fernández et al., 2023). Digital twin-enabled architectures incorporating machine learning risk stratification and real-time alert dissemination are an emerging extension of these principles, with demonstrated performance in hospital pharmacy settings (Jayaprakash et al., 2026).

Layer 3: Network Integration and Interoperability

Layer 3 is the connectivity infrastructure that links the pharmacy to the wider care system, covering general practice, hospital discharge records, and specialist services. This is where interoperability standards become genuinely decisive. A Portuguese implementation within the RM4Health project demonstrated that converting structured medication data from elderly care records into HL7 FHIR MedicationStatement resources is both technically feasible and practically useful: bidirectional data flows between clinical records and research databases were enabled, smart medication dispenser integration was supported, and transcription workload fell, with improved medication safety for older patients with multimorbidity and polypharmacy (Lima et al., 2026). Technical solutions alone are not enough here: the governance dimensions of shared pharmacy data, including privacy, consent, and secondary use, require explicit policy frameworks alongside the technical infrastructure (Khan et al., 2026).

Layer 4: Patient Engagement

Layer 4 is the patient-facing dimension: the digital tools that sustain the pharmacist-patient relationship and generate ongoing adherence and symptom data between visits. This covers mobile health apps, telepharmacy platforms, automated refill reminders, and voice-activated interfaces for patients with sensory or cognitive impairments. Adaptive IoT-based workflows in ambient assisted living settings have demonstrated improved personalised task delivery compared with static designs, with linear scalability as personalisation parameters increase, suggesting that run-time adaptive systems for heterogeneous older adult populations are a practical near-term goal (Sabatucci and Di Napoli, 2025). A Portuguese pharmacy transformation using the mPharmaCare platform combined patient-facing mobile services with back-end pharmacist analytics under the Community Pharmacy 5.0 model and showed genuine improvements in service efficiency and patient engagement (Barata et al., 2022). Smart pills, connected inhalers, and wearable monitors are increasingly part of these patient-centric models, giving pharmacists the means to intervene proactively rather than wait for the next scheduled visit (Kumari et al., 2025).

Three Illustrative Applications in Geriatric Care

Use Case A: Polypharmacy Reconciliation at the Point of Dispensing

A 78-year-old patient arrives for a routine monthly refill of eleven concurrent medications. The automated dispensing system (Layer 1) cross-references the current prescription list against previous dispensing records and the patient's documented drug interaction profile. A Layer 2 alert flags a newly added NSAID as contraindicated given the patient's gastrointestinal risk profile and identifies a gap in proton pump inhibitor coverage. The pharmacist reviews the alert, holds a brief targeted consultation with the patient, and documents a GP referral through the shared Layer 3 EHR. This scenario draws on the Belgian community pharmacy CDSS study (Bogaerts et al., 2024), the Dutch best-practice framework for drug-disease interaction management (Diesveld et al., 2021), and the SystmOne shared EHR pilot from England (Fynn et al., 2026).

Use Case B: Opportunistic Atrial Fibrillation Screening

A 71-year-old patient collecting a diabetes prescription refill is offered a brief single-lead ECG screening using a pharmacy-embedded Layer 1 point-of-care device. An irregular rhythm consistent with atrial fibrillation is detected. The result is transmitted via the Layer 3 infrastructure to the patient's GP record, flagging the finding for clinical review within 48 hours. A Layer 4 mobile notification then informs the patient that their GP has been alerted and provides plain-language information about the finding. This use case draws on the French pharmacy-based AF screening study (Olindo et al., 2022) and shared EHR feasibility data from England (Fynn et al., 2026).

Use Case C: Chronic Disease Adherence Monitoring

An 83-year-old patient with hypertension and type 2 diabetes is enrolled in a combined glucose monitoring and blood pressure telemonitoring programme led by the community pharmacist. Layer 1 sensors generate longitudinal data streams feeding into a Layer 2 analytics dashboard; monthly structured summary reports are shared with the supervising GP via Layer 3. Layer 4 delivers medication reminders and plain-language educational content through a simplified mobile interface with accessibility features suited to older adults with limited digital experience. Rather than waiting for the next scheduled appointment, the pharmacist reviews Layer 2 alerts and initiates medication reviews proactively. This use case draws on evidence from diabetes remote monitoring programmes showing improved adherence through structured pharmacist-led follow-up (Munshi et al., 2021), the USFarmácia programme outcomes (Costa et al., 2023), and a community pharmacy digital transformation case study (Barata et al., 2022).

Discussion

Theoretical and Practical Contribution

The four-layer framework proposed here offers a coherent way to think about the community pharmacy as an IoT-enabled geriatric care node. Its main theoretical contribution is integration: previously separate evidence streams, namely dispensing error research, clinical decision support literature, EHR interoperability studies, patient-facing digital health evidence, and IoT architecture, are brought into a common logical structure. In doing so, the framework makes explicit something each strand of literature tends to leave implicit: the clinical value of any single pharmacy technology depends on how well it connects to the others. A sophisticated point-of-care diagnostic device without Layer 3 connectivity produces an isolated data point, not a care event. A clinical decision support system without reliable Layer 1 dispensing data generates alerts of uncertain validity. The framework treats this interdependence as a design principle rather than a detail.

In practical terms, the modular structure supports phased implementation without demanding full-system transformation from the outset. Systems at an early stage of digital development can invest in Layer 1 first, beginning with automated dispensing and point-of-care diagnostic capacity, and build gradually toward the interoperability requirements of Layer 3. Layer 4 patient-facing tools, often the most visible element of digital pharmacy from the outside, are likely most effective when the underlying data architecture is already in place. The SystmOne pilot supports this sequencing: adoption challenges there were driven by infrastructure and workflow integration problems, not by resistance from pharmacists or patients to the idea of shared digital records (Fynn et al., 2026).

The framework also takes a clear position on something the existing literature has not previously made explicit: the main barrier to pharmacy integration in geriatric care is not a technology gap but a connectivity gap. The evidence reviewed here consistently shows that the clinical components needed for effective geriatric medication management, including dispensing surveillance, decision support, diagnostic capacity, and patient monitoring, already exist and have been validated in community pharmacy settings. What has been missing is the architectural logic that connects them. This matters for investment decisions. Directing resources toward additional device-level innovation yields diminishing returns if the data those devices generate cannot cross care boundaries. Investing instead in Layer 3 interoperability infrastructure, specifically enforcing HL7 FHIR standards and enabling shared EHR access, unlocks the clinical value already latent in installed Layer 1 and Layer 2 components. The framework reframes the policy question accordingly: not what new technologies pharmacies should adopt, but what connectivity conditions must be in place before existing technologies can work as an integrated system.

Barriers and Their Structural Dimensions

The barriers documented across the synthesised literature are structural, not incidental, and they recur consistently across geographic contexts, technology types, and clinical domains. Interoperability failure is the most pervasive. A systematic review of digital determinants of pharmacist readiness confirmed that fragmented health information systems are a key structural barrier limiting access to the patient data needed for informed decision-making; digital literacy and technology-oriented training were cited as enabling factors in 69.2% of included studies (Ait Gacem et al., 2025). The practical consequence is that pharmacy-generated and GP-generated data remain siloed even when they describe the same patient at the same moment, which is precisely the structural problem the four-layer framework targets at Layer 3.

Digital literacy is a barrier on both sides of the consultation. Among pharmacists, technology-oriented competency gaps persist even in high-adoption settings and are the strongest modifiable predictor of IoT implementation readiness (Ait Gacem et al., 2025). Among older patients, the picture is more nuanced than standard assumptions suggest. A feasibility study of QR code-based adherence telemonitoring in 262 elderly cardiac patients found that 75.6% completed the digital task successfully: 83.6% of those aged 65–75 years and 67.9% of those over 75. Crucially, increasing age predicted lower prior smartphone use but did not predict lower ability to learn the task itself. The barrier is interface familiarity, not cognitive incapacity (Capranzano et al., 2021). For Layer 4 tool design, this means that accessible, low-friction interfaces can substantially expand the viable user base among older adults. Evidence from a large Chinese ageing cohort reinforces the wider value of digital engagement: smart health device use was associated with significantly lower odds of depressive symptoms, with digital integration and social participation as key mediating pathways, with effects most pronounced among women and rural residents (Fan et al., 2026).

The equity dimension of IoT-enabled pharmacy is harder to ignore the closer one looks. An analysis of 83,398 US census tracts found that communities with high Digital Divide Index scores were nearly seven times more likely to be pharmacy deserts (OR 6.94), meaning the populations with the least digital access also have the least access to physical pharmacy infrastructure (Catalano et al., 2025). Deploying IoT-enhanced services without attending to this overlap would concentrate the benefits of digital pharmacy among exactly the populations that already have the best access to pharmaceutical care. That is precisely the opposite of the equity goals that digital health advocates routinely claim.

An analysis of 24 nationally recognised smart health demonstration cases in China identified user capability as the critical variable determining whether technologically capable systems actually deliver meaningful outcomes (Mu et al., 2026). The authors extended the standard Technology-Organisation-Environment framework to include capability as a core analytical dimension, arguing convincingly that user capability is not a fixed individual trait but something shaped by governance, service design, and institutional support. For Layer 4 design, the implication is direct: capability building needs to be embedded within the service model from the outset, not treated as a precondition that users are expected to bring with them.

Limitations

Several limitations deserve direct acknowledgement. This is a narrative review, not a systematic one, and it does not include formal risk-of-bias appraisal or quantitative pooling of effect estimates. The framework is conceptual and will require empirical validation through prospective pilot studies before it can support specific implementation recommendations at the system level. The evidence base is predominantly from high-income countries and from the post-2020 period, which limits generalisability to lower-resource settings and may also over-represent digital adoption patterns accelerated by the pandemic that may not persist without that kind of systemic pressure. The three use cases in Section 3.3 are illustrative constructs drawn from multiple evidence sources, not accounts of any single implemented service. Finally, IoT development moves quickly, faster than academic publication cycles, and some specific device capabilities or platform architectures cited here may already have been surpassed by more recent implementation experience.

Conclusion

Community pharmacies have the access, the patient contact, and the emerging digital infrastructure to function as genuine IoT-enabled nodes within geriatric care networks. The four-layer framework developed in this review, covering sensing and capture, local clinical decision support, network integration, and patient engagement, provides a practical architecture for connecting automated dispensing surveillance, point-of-care diagnostic capacity, standards-based interoperability, and patient-facing digital tools into a coherent medication management system for older adults with polypharmacy. Each component of that architecture has been validated individually in community pharmacy settings, with documented reductions in adverse drug reaction rates, dispensing errors, and markers of chronic disease burden across diverse health systems.

Three structural conditions are required. Interoperability standards must be enforced at the health system level, as Layer 3 connectivity cannot be created unilaterally by individual pharmacy organisations, and the value of every other layer depends on it. Investment in pharmacist digital competency must be built into continuing professional education systems, given consistent evidence that digital literacy is the strongest modifiable predictor of IoT adoption success in pharmacy settings. And equity-sensitive deployment must be a design requirement from the outset, explicitly targeting the populations most at risk of digital exclusion, who are frequently the same populations with the heaviest polypharmacy burden and the fewest alternative points of care. Future research should prioritise prospective pilot evaluations of integrated four-layer IoT services in real geriatric care settings, with rigorous measurement of medication safety outcomes, care coordination quality, adherence over time, and equity impacts across digital literacy and socioeconomic groups. The transformation of community pharmacy from passive dispensing site to active, data-generating partner in geriatric care is both empirically grounded and practically achievable. But it will not happen by default. The structural and policy investments identified in this review are what make the difference.

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