

Preventing Medication Errors under Persistent Drug Shortages: A Systems Framework for Therapeutic Substitution, Knowledge Updating, and Safety Governance in Community Pharmacy Practice

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Abstract

Persistent medicine shortages expose community pharmacies to recurrent changes in product availability, therapeutic choices, medication information and professional responsibilities. These disturbances create opportunities for medication errors when substitution decisions, clinical verification and patient communication occur under changing conditions. This article develops a shortage-responsive medication safety framework through a critical conceptual synthesis of literature on pharmaceutical supply disruption, community-pharmacy medication errors, therapeutic substitution, information exchange and organisational safety. The framework identifies the interdependence of supply information, patient-specific treatment decisions, knowledge updating, professional authorisation and incident learning. It distinguishes the operational achievement of maintaining medicine access from the clinical requirements for safe substitution and the separate evidentiary requirement to demonstrate reduced errors. Particular attention is given to information validity, coordination between pharmacists and prescribers, documentation of changed regimens, and responsibility for communicating revised instructions to patients. Adaptive safety governance is conceptualised as an iterative process in which emerging disturbances and reported problems inform subsequent verification and corrective action. The framework provides an analytical basis for developing context-sensitive pharmacy procedures and future empirical evaluation. Its contribution is a proposed systems explanation, not a validated intervention or an estimate of shortage-related medication-error reduction.

Keywords: Drug shortages, Medication errors, Community pharmacy, Therapeutic substitution, Medication information, Patient safety governance

Introduction

Medicine shortages have become a recurrent source of uncertainty in pharmaceutical care. Their consequences extend beyond whether an individual product is available; they may require treatment reassessment,

changes in dispensing arrangements, communication with prescribers and additional explanations to patients. A US analysis demonstrated that reported supply-chain problems and observed reductions in medicine sales are distinct measures, underscoring the importance of differentiating a supply warning from an actual disruption [1]. Comparative evidence from the United States and Canada further indicates that shortage experiences depend on the surrounding pharmaceutical system [2]. Community pharmacies consequently operate within disturbances whose origins, duration and resolution are often outside their direct control.

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Patient consequences are not uniform. A scoping review identified predominantly adverse clinical, economic and humanistic outcomes during medicine shortages, while also documenting circumstances involving equivalent or improved outcomes [3]. This heterogeneity complicates claims that every shortage produces harm. Its relevance to medication safety lies in the decisions required when access becomes uncertain. A prescription may remain clinically appropriate while the prescribed product becomes unavailable; an available alternative may address the supply problem while introducing different administration, dosing, monitoring or communication requirements.

Medication errors in community pharmacies constitute an established patient-safety concern independently of supply shortages. An international systematic review identified variation in error types, study methods and reporting practices, limiting the comparability of published estimates [4]. A broader review of outpatient and ambulatory medication errors likewise demonstrated the diversity of contributing factors and preventive interventions across healthcare settings [5]. These findings establish the importance of analysing pharmacy work processes without attributing all observed errors to medicine scarcity.

The unresolved problem concerns the interaction between recurring availability changes and the organisation of medication decisions. A pharmacist may receive an updated supply notification while a prescriber continues using earlier information; a substitute may be authorised without the patient's current regimen being reconciled; or an incident may be documented without correcting the information used in subsequent decisions. Such situations require an account that connects supply conditions with clinical reasoning, information validity and distributed responsibility.

This article develops a shortage-responsive medication safety framework for community pharmacy practice. Its central question is how stock disturbances, therapeutic substitution, uneven knowledge updating and professional decision rights interact to create or prevent medication errors. The analysis separates published observations from newly proposed systems relationships and treats the framework as a basis for safety-oriented organisational design and subsequent evaluation.

Persistent drug shortages as a medication safety systems problem

Persistent shortages place pharmacies at the downstream end of a supply system in which manufacturing, sourcing, distribution and regulatory information may change independently of the patient's treatment needs. Mapping of upstream supply chains for commonly used medicines in the Netherlands demonstrates the relevance of dependencies beyond the immediate dispensing environment [6]. Analysis of active pharmaceutical ingredient production for US generic medicines experiencing shortages similarly locates important supply characteristics outside individual pharmacy organisations [7]. A community pharmacy can respond to a missing product, but it cannot independently restore manufacturing capacity or guarantee wholesale availability.

Supply disturbance becomes a medication-safety problem through its interaction with clinical work. A review of disruption-related utilisation found that shortages may alter medicine use across products and settings [8]. Such changes create additional decisions about the prescribed treatment, available alternatives and continuity of supply. German pharmacists have reported safety concerns associated with shortages, providing practice-based evidence of operational pressure without establishing the population incidence of resulting medication errors [9].

Qualitative accounts from community pharmacists identify the practical challenges of managing medicine shortages during disruptive circumstances [10]. Research examining shortages in community pharmacies also connects availability problems with consequences for patients and healthcare systems [11]. These experiences illustrate how procurement uncertainty can be transferred into professional work: confirming availability, contacting prescribers, responding to patient concerns, managing incomplete supplies and explaining revised arrangements. Each additional interaction may contribute to safe continuity, yet incomplete or inconsistent handoffs may introduce a new opportunity for misunderstanding.

Institutional context affects the options available to pharmacies. A comparison of shortage-management approaches across 24 countries identified variation in national responses [12]. Substitution authority, reimbursement, reporting requirements and communication channels therefore require jurisdiction-specific interpretation. A procedure that is administratively feasible in one system cannot be assumed to be lawful or workable in another.

The relevant disturbance is consequently a changing relationship between supply information and the conditions needed to provide an individual patient's treatment. A stock notice may be current at one organisational level but outdated locally. A product may become available after another treatment has been authorised. The patient may receive instructions reflecting an earlier decision. These temporal mismatches are proposed mechanisms requiring direct investigation; existing shortage reports and utilisation data do not measure them as a single causal pathway.

Therapeutic substitution and the emergence of new medication risks

Therapeutic substitution introduces clinical questions that cannot be settled by product availability alone. Changes may involve the strength of an existing medicine, a different formulation, an alternative active ingredient or a revised regimen. Their implications depend on indication, pharmacological characteristics, patient history, concurrent treatment, route of administration, monitoring requirements and the authority under which the change occurs.

Evidence of changed utilisation illustrates the importance of this distinction. A study of community antibiotic use examined how shortages were associated with alterations in utilisation [13]. Such observations identify changes in medicine use but cannot establish whether each altered prescription was clinically appropriate. Australian dispensing data for lisdexamfetamine similarly showed changes across product strengths during notified

shortages [14]. Aggregate dispensing patterns could reflect changes in prescribing or patient behaviour, but they do not reveal the clinical suitability of an individual patient's revised regimen.

Substitution concerns also vary with the medicine involved. A national survey of pharmacists' beliefs and practices regarding generic substitution of narrow-therapeutic-index medicines demonstrates the relevance of professional judgement in product changes requiring particular clinical attention [15]. The survey does not establish that all generic alternatives are unsafe. It supports recognising that product equivalence, clinical suitability and the patient's actual use are separate matters.

An important error opportunity arises when a changed product is interpreted through instructions belonging to the original product. Strength, dosage form, administration technique, dose calculation and treatment schedule may become inconsistent across the prescription, dispensing record and patient understanding. A further hazard occurs when a temporary shortage arrangement remains in place after availability changes. The relationship between the initial disturbance and the eventual error may therefore be indirect and time-dependent.

The relevant safety task is to identify which properties of the original treatment remain clinically applicable, which require renewed verification and what must be communicated before dispensing. These distinctions establish the hazard-control relationships in **Table 1**.

Table 1. Shortage disturbances, potential medication-error mechanisms and patient-specific preventive controls

Shortage disturbance	Potential error mechanism	Patient-specific verification	Proposed preventive control
Prescribed strength unavailable	Instructions retained despite a changed strength or quantity	Intended dose, formulation and actual administration	Reconcile revised directions with the authorised treatment and dispensed product
Original formulation unavailable	Administration requirements or release characteristics overlooked	Formulation suitability, route and patient capability	Require formulation-specific clinical review before substitution
Alternative active ingredient considered	Assumed therapeutic interchangeability or inappropriate regimen	Indication, allergies, contraindications, interactions and monitoring needs	Obtain the appropriate clinical authorisation and communicate the revised treatment
Availability changes during dispensing	Earlier stock or treatment information used for a later decision	Current product availability and validity of the treatment decision	Recheck the relevant information before completing the affected transaction
Temporary substitution continues after supply restoration	Conflicting old and revised treatment instructions	Current regimen, previous supply and patient-held medicines	Reconcile treatment status and communicate whether the temporary arrangement continues

Note: The table presents proposed hazard-control relationships developed from the approved evidence reservoir. It does not report measured error frequencies, tested control effectiveness or universal substitution permissions. All clinical decisions remain subject to patient-specific review and applicable professional and regulatory requirements.

Knowledge updating under rapidly changing availability and treatment conditions

Safe shortage management depends on the continuing validity of information used to make and communicate treatment decisions. Availability notices, prescription records, professional recommendations and patient instructions may originate from different organisations and may be updated at different times. The problem is especially consequential when an earlier decision was appropriate under conditions that no longer apply.

Research on medication changes across care transitions identified opportunities to strengthen patient and family involvement, including gaps in communication when treatment decisions were made [16]. Although transitions of care differ from shortages, both contexts require a changed medication plan to be understood across professional and patient-facing settings. The proposed application to shortages is that the communication process must distinguish the reason for a change, the treatment actually authorised and the instructions currently applicable to the patient.

Hämeinen-Anttila and Mikkola have argued for greater consistency in community-pharmacy medication counselling, highlighting variation in counselling quality and the need to consider the wider pharmacotherapy process [17]. Under shortage conditions, standardising the core information to be communicated could reduce ambiguity while allowing adaptation to individual needs. Such a standard would specify the information required for a safe conversation, without treating a uniform message as sufficient for every patient.

Information validity also depends on institutional context. A compilation of governmental shortage policies across 38 countries documented evolving responses during and after the COVID-19 pandemic [18]. National policy information, local availability and individual clinical authorisation consequently represent different information categories. A current regulatory notice may inform a decision without establishing what a particular pharmacy can supply or what a specific patient should receive.

For this framework, a versioned medication decision is proposed as an identifiable treatment state linking the source and effective time of relevant information to the authorised regimen and subsequent communication. Its practical information requirements include the affected product, the reason for change, the decision owner, the applicable instructions and any unresolved issue requiring follow-up. Versioning is a conceptual design

principle here; the approved evidence does not establish that implementing a particular digital record or timestamping system reduces shortage-related errors.

A change in stock information should trigger reconsideration only where it affects an active treatment decision. Conversely, a clinically revised regimen should be reflected in the pharmacy's working information and the instructions received by the patient. The central safety concern is the continued use of information after its applicable treatment conditions have changed.

Development of the shortage-responsive medication safety framework

The shortage-responsive medication safety framework is organised around the interaction of supply conditions, therapeutic choice, information validity, professional authority and patient-facing treatment. Its central proposition is that these elements require coordinated reassessment whenever a shortage disturbance changes the conditions under which a previous medication decision was made.

Evidence from a qualitative assessment of collaborative shortage management identified simultaneous shortage-management strategies, insufficient resources or lead time, and differing attitudes toward collaboration [19]. These findings establish that coordination itself has practical constraints. A shared information resource may support decisions, but its existence cannot guarantee timely clinical assessment or agreement between professionals.

The information-transfer problem can be examined through related medication-safety research. A quality-improvement study of electronic transmission of discharge medication information provides a bounded example of how information exchange and medication discrepancies may be investigated [20]. Its hospital-discharge context differs from community-pharmacy substitution. The relevant contribution is methodological: the transmission of information and the correctness of the resulting medication state should be assessed separately.

Organisational readiness also requires qualification. A Finnish community-pharmacy crisis-management study found context-dependent associations between management practices and organisational outcomes; pre-existing pandemic plans were not uniformly protective of pharmacy resources [21]. This challenges any assumption that formal procedures alone constitute effective shortage governance. Procedures must be

connected to usable information, practical decision authority and the resources needed to carry out verification.

The proposed framework distinguishes five interacting functions. First, supply interpretation establishes whether an availability signal affects an active prescription or anticipated refill. Second, therapeutic assessment determines whether a potential change is clinically suitable for the individual patient. Third, knowledge updating establishes which information and treatment instructions remain applicable. Fourth, accountable authorisation distinguishes who supplies information, who makes or confirms the clinical decision and who communicates it. Fifth, safety feedback identifies discrepancies and concerns that require subsequent correction.

These functions are mutually dependent but operate at different levels. Supply information may originate from manufacturers, distributors or public authorities; treatment decisions involve authorised clinicians; the pharmacy translates an authorised regimen into a dispensing and counselling encounter; and patients

contribute information about actual medicine use, understanding and feasibility. A product-level shortage cannot automatically determine a patient-level therapeutic decision. The framework therefore places patient-specific applicability between candidate substitution and treatment authorisation.

Three relationships give the framework its distinctive explanatory purpose. An availability change can reopen a previously completed medication decision. A revised clinical decision can make an earlier instruction obsolete even when the supply information itself remains accurate. A reported discrepancy can indicate that information, authorisation or patient communication requires reassessment. These relationships are proposed systems inferences from the preceding evidence, not empirically established causal pathways.

Figure 1 represents the resulting adaptive safety field. Its cross-links distinguish information movement from clinical decision authority, while the patient-specific applicability condition prevents an available product from being interpreted as an automatically acceptable substitute.

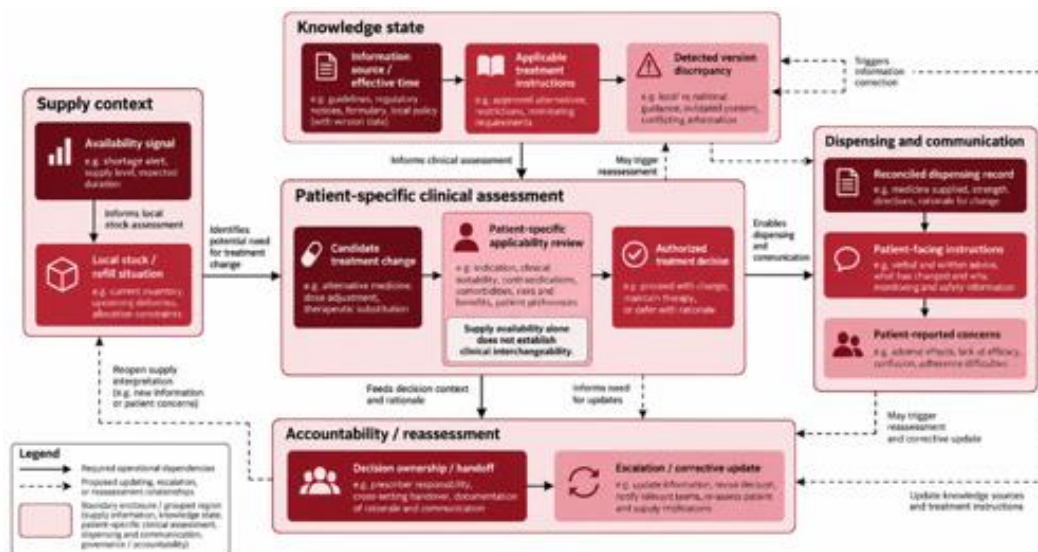


Figure 1. Clinical decision authority within the changing information conditions of a medicine shortage

Clinical verification, communication, and substitution governance

Clinical verification is the point at which a potential shortage response becomes an individual treatment decision. Availability information may identify possible alternatives, but the proposed change must be assessed against the patient's current treatment, relevant clinical characteristics and applicable professional authority. The

verification process therefore concerns the validity of the entire revised regimen, including the medicine, strength, formulation, administration instructions and monitoring requirements.

The Finnish national medication-safety programme for community pharmacies provides an example of organised medication-safety development across pharmacy practice [22]. Its implementation experience

supports consideration of structured safety activities but does not establish that a particular shortage-substitution procedure reduces errors. Documentation is equally important. A European scoping review of drug-related-problem identification and documentation demonstrates the diversity of recording practices in community pharmacies [23]. For shortage governance, the proposed requirement is to preserve a retrievable connection between the original treatment, the reason for change, the authorised alternative and the instructions ultimately communicated to the patient.

Clinical decision support may assist verification without replacing professional judgement. A simulation trial of a medication-review decision-support system illustrates the potential to examine structured support for complex medication decisions [24]. Research reviewing artificial-intelligence approaches to medication-alert optimisation identifies opportunities to improve the information presented to clinicians [25]. Neither evidence source establishes that an automated recommendation can determine clinical interchangeability or independently authorise a shortage-related substitution.

The distinction between receiving an alert and achieving a safer outcome is particularly important. A systematic review of electronic drug–drug interaction alerts

examined both patient and clinician outcomes, demonstrating the need to evaluate consequences beyond alert generation or acceptance [26]. A substitution warning should therefore identify a clinically relevant concern and the action needed to resolve it. Repeated, poorly targeted messages may add work without resolving uncertainty.

Pharmacist-led medication reconciliation offers a related model of responsibility for maintaining a coherent medication record across care settings [27]. In shortage-responsive practice, reconciliation must account for temporary treatments and subsequently superseded instructions. The responsible professional should establish what the patient is actually taking, whether the revised treatment remains authorised and whether additional prescriber involvement is required.

Patient communication completes this clinical process. Patients need to understand which medicine they should now use, whether the dose or administration differs, what to do with previously supplied products, and when to seek further advice. Confirmation of understanding is especially relevant where changes create a risk of using both the original and replacement treatment. **Table 2** specifies the proposed relationship between substitution circumstances, verification and escalation.

Table 2. Patient-specific verification and authorisation requirements during shortage-related treatment changes

Substitution circumstance	Required clinical information	Decision responsibility	Communication and escalation
Alternative brand or presentation considered	Active ingredient, formulation, strength and product-specific instructions	Pharmacist within applicable substitution authority	Explain product differences and confirm patient understanding
Strength or dosing arrangement changes	Intended total dose, dosing schedule and administration feasibility	Appropriate authorised clinician; pharmacist verifies the dispensing instructions	Confirm the revised regimen and resolve inconsistent directions
Different active ingredient proposed	Indication, treatment history, contraindications, interactions and monitoring needs	Authorised prescriber or other professional with applicable prescribing authority	Obtain and document authorisation before supplying the revised treatment
Temporary shortage arrangement requires reassessment	Current regimen, medicines already supplied and updated availability	Responsible clinician and dispensing pharmacist within their respective roles	Clarify whether the temporary treatment continues or is replaced
Essential information or authorisation is missing	Outstanding clinical, prescription or patient-specific information	Professional authorised to resolve the uncertainty	Escalate before completing the affected substitution; explain the delay and available follow-up arrangements

Note: This proposed authorisation matrix describes functions rather than universally applicable legal permissions. Professional authority, prescribing requirements and permitted substitution arrangements must be determined under the relevant jurisdiction. No row establishes clinical equivalence without individual assessment.

Organizational accountability and interprofessional coordination

Persistent shortages distribute medication-safety responsibilities across organisations that possess

different information and decision rights. Manufacturers and distributors may identify supply changes, pharmacies observe local stock and dispensing consequences, prescribers retain responsibility for treatment decisions

within their authority, and patients provide information about actual medicine use and treatment feasibility. Regulatory bodies and payers establish additional conditions affecting available responses.

A national survey of community-pharmacy patient-safety climate illustrates the relevance of organisational conditions to safety practice [28]. However, safety climate cannot substitute for evidence that a specific shortage procedure prevents errors. Accountability must be expressed through identifiable duties, workable handoffs and the capacity to respond when a decision cannot be completed safely.

The proposed governance arrangement separates four responsibilities: maintaining relevant supply information, assessing patient-specific treatment suitability, documenting the authorised change and

communicating its consequences. These functions may be performed by different people, but responsibility for completing the handoff must remain identifiable. An organisation should not interpret the transmission of a message as confirmation that another professional has received, understood or acted upon it.

Coordination also requires a means of resolving disagreement. A wholesaler's availability notification cannot settle a clinical question; a prescriber's treatment choice cannot guarantee local supply; and a pharmacy's dispensing record may not reflect medicines obtained elsewhere. Unresolved discrepancies require escalation to the professional or organisation possessing the relevant authority. **Table 3** locates these responsibilities without assuming identical arrangements across health systems.

Table 3. Distributed responsibilities and potential accountability gaps in community-pharmacy shortage management

Actor or setting	Shortage-information duty	Decision authority or operational responsibility	Required handoff	Potential accountability gap
Manufacturer or distributor	Communicate relevant supply changes through applicable channels	Supply and distribution decisions within regulatory obligations	Updated availability information to downstream organisations	Delayed or incomplete information about changing supply
Community pharmacy	Verify local availability and maintain the current dispensing information	Dispensing, permitted substitution and professional verification	Product status, unresolved concerns and patient-facing instructions	Stock information disconnected from the authorised treatment
Prescriber or authorised clinician	Assess treatment implications of unavailable medicines	Patient-specific treatment decisions within professional authority	Revised prescription or documented clinical instruction	Treatment decision not reflected in dispensing or patient records
Patient or caregiver	Communicate actual medicine use, access difficulties and concerns	Participation in treatment decisions and implementation of agreed instructions	Confirmation of the current regimen and outstanding questions	Conflicting instructions or unrecognised concurrent use
Regulatory or reimbursement authority	Communicate applicable shortage measures and policy changes	Decisions within the relevant statutory or reimbursement remit	Current permissions and requirements to affected organisations	Local practice relying on superseded policy information

Note: This table represents proposed functional accountability. Specific statutory duties and substitution permissions require local verification. Information transfer does not by itself confirm completion of a clinical or organisational decision.

Safety monitoring, incident learning, and adaptive system improvement

Safety monitoring under persistent shortages must capture both recognised medication errors and the conditions that make subsequent errors possible. A reported event may concern an incorrect product, dose, formulation, instruction or handoff. A near miss may identify the same underlying weakness before the patient receives an inappropriate treatment. Monitoring should therefore retain information about the shortage disturbance and the medication decision, while

distinguishing actual patient outcomes from potential hazards.

Analysis of an Australian community-pharmacy incident-reporting system demonstrates the value of examining incident nature, severity and contributing causes [29]. For the proposed framework, reports should connect the affected treatment to the information and authorisation available when the event occurred. This allows an organisation to investigate whether a discrepancy originated in an outdated stock notice, an

incomplete clinical review, conflicting dispensing instructions or a failed communication handoff.

Longitudinal reporting requires particular caution. A Finnish national retrospective study analysed dispensing errors reported by community pharmacies over several years [30]. Changes in reported events can reflect changes in the occurrence of errors, but also detection, reporting behaviour and organisational participation. A greater number of reports may therefore accompany improved recognition of problems. Evaluation must retain suitable denominators and distinguish reporting performance from actual patient-safety outcomes.

Incident learning also has a professional dimension. Consensus research addressing the second-victim phenomenon among community pharmacists identifies the importance of supporting professionals affected by medication incidents [31]. A learning arrangement that concentrates exclusively on individual blame may discourage reporting or conceal organisational

contributors. The proposed response combines appropriate professional accountability with opportunities to identify weaknesses in information exchange, workload arrangements and clinical verification.

Corrective action should address the level at which the problem originated. An incorrect patient instruction requires reconciliation and communication; a recurrent local stock-information discrepancy may require a revised updating procedure; an unresolved substitution policy may require external clarification. Responsibilities for implementing and confirming corrective action should be explicit.

Figure 2 depicts two related learning cycles: the immediate correction of an affected medication decision and the slower revision of information and organisational arrangements. Recurrent disturbances can reopen both cycles, while cross-organisational alerts connect lessons that would otherwise remain isolated.

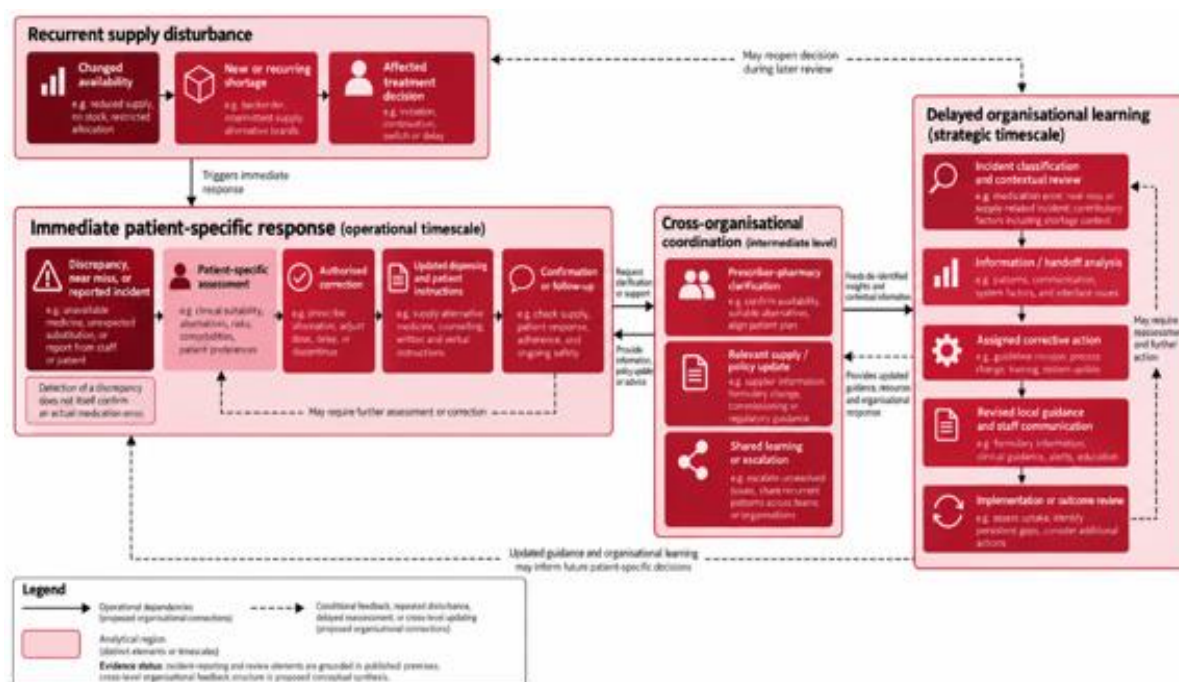


Figure 2. How recurrent medicine shortages generate immediate correction and delayed organisational learning

Implementation implications for community pharmacy practice

Implementation should begin with the pharmacy's existing prescribing, dispensing, counselling and incident-reporting processes. A shortage response becomes more manageable when responsibility for checking availability information, obtaining necessary

authorisation and updating patient instructions is assigned within ordinary work arrangements. The relevant information must remain accessible to the professional completing the affected transaction.

The proposed minimum process begins when a shortage affects an active prescription. The pharmacist establishes the current availability situation, identifies any proposed

treatment change and determines whether the available information supports patient-specific verification. Where clinical suitability or authority remains unresolved, the decision is escalated rather than completed through an assumption of interchangeability. Once the appropriate decision has been made, the pharmacy reconciles the dispensing record and communicates the applicable instructions.

Temporary arrangements require particular attention during subsequent refills. The current regimen should be confirmed against previous supplies and any new clinical instructions. Changes in availability may justify reassessment, but restoration of the original product does not automatically require reversal of an authorised treatment change.

Implementation also requires attention to workload, electronic interoperability and unequal pharmacy resources. A procedure dependent on uninterrupted electronic exchange may require a documented alternative when systems are unavailable. Smaller pharmacies may need shared information resources or clearly established external escalation arrangements. These adaptations should preserve clinical verification and accountability without assuming that every pharmacy possesses identical staffing or technical capacity.

Evaluation should measure the outcomes the intervention is intended to change. A pharmacy-based study examining the sustained effectiveness of an intervention for older adults' over-the-counter medication misuse reported nonsignificant findings, illustrating the importance of distinguishing implementation from demonstrated benefit [32]. For shortage-responsive practice, process measures may include completed verification, documented authorisation and communication, while patient-safety evaluation requires appropriately defined error and harm outcomes. No effectiveness claim follows solely from adopting the proposed framework.

Results and Discussion

Persistent medicine shortages expose a coordination problem in which information, clinical decisions and organisational responsibilities may change at different times. The framework developed here identifies how these changes can affect medication safety through patient-specific substitution, the validity of treatment instructions and the completion of professional handoffs.

Its central contribution is an account of how a recurrent supply disturbance can reopen a previously appropriate medication decision.

This account requires several qualifications. Shortage-related changes in utilisation cannot establish that an alternative treatment was inappropriate or that a medication error occurred. Patient outcomes are heterogeneous, and maintaining access may itself be an important benefit. The relevant safety question is whether a changed treatment remains clinically suitable, correctly authorised and understood by the patient.

The organisational relationships also remain conditional. A written shortage procedure may be ineffective when staff cannot obtain timely information or when decision responsibilities are unclear. Electronic alerts may support recognition of medication concerns without demonstrating improved patient outcomes. Conversely, incomplete digital infrastructure does not establish that safe substitution is impossible where reliable professional communication and documentation are available.

Alternative explanations must be considered when evaluating the model. Changes in prescribing, patient demand, staffing, reimbursement and reporting behaviour may affect observed outcomes independently of shortage procedures. Differences between jurisdictions constrain the transfer of authorisation arrangements. Patients with complex treatment regimens or limited access to follow-up may encounter additional difficulties that are not adequately represented by product-level supply information.

Future empirical investigation should therefore examine specific mechanisms rather than treat the framework as a single undifferentiated intervention. Relevant questions include whether outdated information contributes to discrepancies, whether authorisation and communication are completed reliably, and whether corrective actions address recurrent problems. Evaluation should distinguish incident detection from true error occurrence and examine whether improvements persist across repeated disturbances.

The framework offers a structure for such investigation while preserving the distinction between its evidence-supported premises and its proposed relationships. Its practical significance depends on whether pharmacies and their collaborating organisations can translate these relationships into feasible, patient-specific procedures and evaluate their consequences.

Conclusion

Persistent drug shortages create medication-safety challenges through repeated changes in availability, treatment choices, information and professional responsibilities. The proposed shortage-responsive framework connects these conditions through patient-specific verification, accountable authorisation, coordinated communication and adaptive incident learning. It identifies how a supply disturbance may require reassessment of a previously appropriate treatment and how outdated information or incomplete handoffs may contribute to medication-error opportunities. Maintaining access, ensuring appropriate substitution and demonstrating fewer medication errors remain distinct objectives. The framework provides an evidence-bounded basis for developing and evaluating community-pharmacy safety procedures, without claiming that its proposed relationships or interventions have been empirically validated.

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