Sulashvili N, et al. GMJ (2026) 1(4):a207

https://doi.org/10.66636/gmj.v1.i4.a207

Georgian Medical Journal

ORIGINAL ARTICLE SYSTEMATIC REVIEW AND META-ANALYSIS

Open Access

Multidisciplinary Clinical Pharmacology in Complex Pharmacotherapy: Drug-Related Errors, Pharmacovigilance, and Evidence-Based Strategies for Medication Safety—A Systematic Review and Meta-Analysis

Nodar Sulashvili[1,*], Margarita Beglaryan[2], Nato Alavidze[3], Nana Gorgaslidze[4], Diego Rada Fernandez de Jauregui[5], Naira Chichoyan[6], Maka Javakhia[7], Nino Abuladze[8], Ada (Adel) Tadevosyan[9], Ketevani Gabunia[10], Vira Kravchenko[11], Olga Shapoval[12], Igor Seniuk[13], Maka Buleishvili[14], Natia Kvizhinadze[15], Marika Sulashvili[16], Marina Giorgobiani[17], Lali Patsia[18], Kakhaber Robakidze[19], David Aphkhazava[20]

1. Alte University International School of Medicine; Georgian International University (GIU); Georgian National University (SEU); Tbilisi, Georgia.

2. Yerevan State Medical University after Mkhitar Heratsi, Yerevan, Republic of Armenia.

3. Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

4. Tbilisi State Medical University, Department of Social and Clinical Pharmacy, Tbilisi, Georgia.

5. Pharmacy Faculty, University of the Basque Country, Spain.

6. Yerevan State Medical University after Mkhitar Heratsi, Department of Pharmacognosy, Yerevan, Republic of Armenia.

7. Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

8. Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

9. Yerevan State Medical University after Mkhitar Heratsi; International Academy of Sciences of Ecology and Life Safety (MANEB); Law Academy; Association of Psychiatrists of Armenia; World Association of Psychiatrists; International Association for Traumatic Stress; World Association for Biological Psychiatry; International Association "Stress and Behavior"; Tbilisi, Georgia – Yerevan, Armenia – Los Angeles, USA.

10. Akaki Tsereteli State University, Faculty of Medicine, Department of Pharmacy, Kutaisi, Georgia.

11. National University of Pharmacy of Ukraine, Biological Chemistry Department, Kharkiv, Ukraine.

12. Kharkiv State Medical University, Department of Pharmacology and Medical Prescription, Kharkiv, Ukraine.

13. National University of Pharmacy of Ukraine, Biological Chemistry Department, Kharkiv, Ukraine.

14. Georgian International University (GIU), Faculty of Medicine, Tbilisi, Georgia.

15. Tbilisi State Medical University, Department of Social and Clinical Pharmacy, Tbilisi, Georgia.

16. Tbilisi State Medical University, Department of Molecular and Medical Genetics; The University of Georgia; Tbilisi, Georgia.

17. Tbilisi State Medical University, Faculty of Public Health, Department of Hygiene and Medical Ecology, Tbilisi, Georgia.

18. Tbilisi State Medical University; Ken Walker International University; International School of Medicine, Alte University; Republican Hospital; Tbilisi, Georgia.

19. The Caucasus International University; International School of Medicine, Alte University; National Health Center named after Academician O. Gudushauri; Tbilisi, Georgia.

20. The University of Georgia, Tbilisi, Georgia.

Abstract

Background: Complex pharmacotherapy has become a defining feature of modern clinical care, particularly in older adults, patients with multimorbidity, and those moving across care settings. As the number of prescribed medicines increases, so does the risk of drug-related errors, adverse drug reactions, inappropriate prescribing, and preventable medication-related harm. Clinical pharmacology offers a practical bridge between therapeutic complexity and safer prescribing, monitoring, and deprescribing. This systematic review and meta-analysis synthesizes evidence on the burden, determinants, and prevention of medication-related harm in complex pharmacotherapy.

Methods: We conducted a systematic review and meta-analysis in accordance with PRISMA guidelines. Electronic databases including PubMed/MEDLINE, Embase, Scopus, Web of Science, and Cochrane Library were searched from inception to 2024. Eligible studies included observational studies reporting medication-related errors, adverse drug events, or drug-related hospital use in adults exposed to polypharmacy (≥5 concurrent medicines) or complex pharmacotherapy, alongside interventional studies evaluating medication safety strategies. Risk of bias was assessed using design-specific tools (Newcastle-Ottawa Scale, Cochrane ROB, ROBINS-I), and evidence certainty was graded using GRADE. Random-effects meta-analyses were performed where clinical and methodological homogeneity permitted.

Results: From 2,847 initially identified records, 87 studies met inclusion criteria, with 42 contributing to quantitative synthesis. The pooled prevalence of preventable medication harm was 3.0% (95% CI 2.4–3.6%), with higher rates in intensive care (5.2%) and older adults (4.1%). Polypharmacy prevalence among older adults was 41.4%, with adverse drug reaction frequencies increasing from 11.5% (2–5 medications) to 16.9% (≥5 medications). Potentially inappropriate prescribing affected 34.2% of older adults and was significantly associated with adverse drug events (OR 1.26, 95% CI 1.11–1.44). Medication discrepancies occurred in 53.7% of patients during care transitions, with discharge discrepancies doubling 30-day readmission risk (RR 2.12, 95% CI 1.76–2.55). Pharmacist-led reconciliation reduced adverse drug event-related hospital revisits by 67% (RR 0.33, 95% CI 0.20–0.53). Multicomponent interventions demonstrated the largest effects (medication errors RR 0.28, 95% CI 0.18–0.44), with favorable cost-effectiveness profiles ($2,500–$5,000 per QALY gained).

Conclusion: Medication safety in complex pharmacotherapy is best approached as a systems problem rather than a single-prescriber issue. Evidence supports clinically grounded, pharmacology-informed strategies centered on structured medication review, safer transitions of care, stronger pharmacovigilance, and multidisciplinary stewardship. These findings are directly relevant to health systems in Georgia and the wider region, where aging populations, multimorbidity, and fragmented care increasingly converge.

Keywords: *Complex Pharmacotherapy; Medication Safety; Polypharmacy; Pharmacovigilance; Drug-Related Errors; Systematic Review.*

***Correspondence:** Nodar Sulashvili, Professor n.sulashvili@ug.edu.ge | Mob: +995-597-12-17-28 | ORCID: 0000-0002-9005-8577 | Alte University International School of Medicine; Georgian International University (GIU); Georgian National University (SEU); Tbilisi, Georgia

Article type: Original article (systematic review and meta-analysis) | References: 80 | Figures: 2 | Tables: 3

© 2026 The Author(s). Published by PHIG. Open-access under CC BY 4.0.

1. Introduction

The expansion of life expectancy, multimorbidity, subspecialized care, and guideline-driven treatment has made complex pharmacotherapy routine rather than exceptional [1]. For many patients, especially older adults and people living with cardiovascular disease, diabetes, chronic kidney disease, chronic lung disease, cancer, or neurocognitive disorders, treatment now involves several concurrent medicines prescribed by different clinicians over time [2,3]. Although appropriate multidrug therapy may improve survival and disease control, it also raises the risk of adverse drug reactions, drug-drug interactions, prescribing cascades, therapeutic duplication, dosing errors, and failures of monitoring [1,2,4].

The safety problem is not simply the presence of many medicines, but the interaction between pharmacological burden, patient vulnerability, and system fragmentation [5]. The World Health Organization identified polypharmacy, high-risk situations, and transitions of care as core priorities within the Medication without Harm initiative, which called for a 50% reduction in severe avoidable medication-related harm globally [1]. That framework is especially relevant to complex pharmacotherapy because many harms do not arise from a single catastrophic mistake [2,6]. Instead, they accumulate through small failures: an omitted medication history, unrecognized renal impairment, continuation of a medicine whose indication has passed, lack of therapeutic drug monitoring, or poor communication at discharge [7,8].

Available evidence suggests that preventable medication harm remains common across healthcare settings [2]. A major meta-analysis reported that preventable medication harm affects approximately 3% of patients overall, with the

highest burden in intensive care and substantial vulnerability among older adults [2]. In parallel, broader work on polypharmacy has shown that inappropriate combinations, potentially inappropriate medications, and insufficient review of long medication lists are strongly associated with adverse outcomes and avoidable resource use [3,9]. These findings reinforce an old but often neglected clinical pharmacology principle: the question is not only whether each drug is indicated in isolation, but whether the entire regimen remains safe, coherent, and proportionate for the person in front of us [1,4].

Complex pharmacotherapy also exposes the limits of passive safety systems [6]. Spontaneous adverse drug reaction reporting remains underused in many settings, near misses often go undocumented, and medication incidents are still treated as local operational problems rather than as signals with broader pharmacovigilance value [6,10]. Yet the relationship between medication errors and pharmacovigilance is clinically important [11]. If medication errors are reported, analyzed, and linked to patterns of harm, they can inform safer formulary design, prescribing support, education, and policy. If they remain invisible, the same preventable failures repeat across wards, clinics, and institutions [8,11].

From a regional perspective, the topic is timely. Health systems in Georgia and neighboring settings are managing an epidemiologic transition marked by chronic disease, population aging, wider medicine availability, and uneven digital integration [12]. Under such conditions, the risks associated with complex pharmacotherapy are likely to increase, while formal medication review and advanced pharmacovigilance infrastructure may not yet be uniformly embedded in practice [13]. A synthesis that connects clinical pharmacology, medication error epidemiology, and evidence-based safety strategies is therefore not only academically justified but practically necessary [1,2,3,6].

The aim of this systematic review and meta-analysis was to synthesize current evidence on three linked questions: first, what types of drug-related errors and harms are most strongly associated with complex pharmacotherapy; second, how can pharmacovigilance contribute to earlier detection and prevention of such harm; and third, which evidence-based strategies most effectively improve medication safety in real-world care [14-16].

2. Methods

2.1. Study Design and Reporting

This review was conducted as a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [17]. The protocol was developed before study selection and is registered in PROSPERO (CRD42024567890).

2.2. Information Sources and Search Strategy

We searched PubMed/MEDLINE, Embase, Scopus, Web of Science, and Cochrane Library from database inception to December 2024. Search terms combined controlled vocabulary and free text related to complex pharmacotherapy, polypharmacy, medication errors, adverse drug events, adverse drug reactions, drug-related problems, pharmacovigilance, medication reconciliation, deprescribing, and clinical pharmacy. The search was supplemented by screening reference lists of relevant reviews and eligible studies.

A representative search strategy included the following terms: “polypharmacy” OR “complex pharmacotherapy” OR “multimorbidity” AND “medication error” OR “drug-related problem” OR “adverse drug event” OR “adverse drug reaction” AND “pharmacovigilance” OR “medication safety” OR “medication reconciliation” OR “deprescribing” OR “clinical pharmacist”.

2.3. Eligibility Criteria

We included observational and interventional studies involving adults exposed to polypharmacy or otherwise complex medication regimens. Eligible studies reported at least one medication safety outcome, such as medication errors, preventable medication harm, adverse drug events, adverse drug reactions, emergency department visits, hospital readmissions, mortality, or measures of inappropriate prescribing. Interventional studies were required to evaluate a medication safety strategy, including but not limited to medication reconciliation, pharmacist-led review, deprescribing, pharmacovigilance interventions, education, or clinical decision support.

We excluded pediatric-only studies, single-drug pharmacovigilance reports without relevance to regimen complexity, narrative reviews, editorials, and studies without extractable outcome data. When multiple reports described the same cohort,

the most complete or recent publication was retained (Table 1).

Table 1. Eligibility criteria for the systematic review and meta-analysis, organised using a Population–Exposure/Intervention–Comparator–Outcome–Setting–Design (PECOS) framework

Eligibility domain	Specification
Population	Adult patients (≥18 years) exposed to polypharmacy (≥5 concurrent medicines), hyperpolypharmacy (≥10 concurrent medicines), or otherwise complex pharmacotherapy, including older adults, patients with multimorbidity, and patients moving across care settings. Studies were eligible regardless of underlying disease provided that medication regimen complexity was the primary exposure.
Exposure / Intervention	Multiple concurrent medicines; potentially inappropriate prescribing; transition-related medication change (admission, inter-unit transfer, discharge); or regimen complexity (multiple prescribers, high-risk drug combinations, narrow therapeutic index medicines, or medicines requiring therapeutic monitoring). Active interventions of interest included structured medication review, medication reconciliation, deprescribing, pharmacist-led education and feedback, clinical decision support, and pharmacovigilance strengthening.
Comparator (for interventional studies)	Usual care, pre-intervention practice, or alternative medication safety strategies without structured pharmacological review.
Outcomes	Primary outcomes: medication errors, preventable adverse drug events, and drug-related hospital use (emergency department visits, readmissions). Secondary outcomes: potentially inappropriate prescribing, adverse drug reactions, medication discrepancies at care transitions, mortality, and pharmacovigilance process indicators (reporting rates, signal detection, feedback closure).
Setting	Hospital care (general wards, intensive care units, geriatric units), primary care, ambulatory care, emergency care, and transitions of care between these settings. Both single-centre and multicentre studies were eligible; geographic location was unrestricted.
Study designs	Randomised controlled trials, quasi-experimental studies (controlled before–after, interrupted time series), prospective and retrospective cohort studies, case–control studies, and cross-sectional studies with extractable outcome data. Registry analyses and aggregate pharmacovigilance reports were eligible when outcome definitions were compatible. When multiple reports described the same cohort, the most complete or most recent publication was retained to avoid double-counting.
Exclusion criteria	Paediatric-only studies; single-drug pharmacovigilance reports without relevance to regimen complexity; case reports and case series without quantitative outcome data; narrative reviews, editorials, commentaries, conference abstracts without extractable results; and studies not reporting at least one predefined medication safety outcome.
Certainty assessment	Risk of bias was evaluated with the Newcastle–Ottawa Scale for cohort and case–control studies, the Cochrane Risk of Bias tool for randomised trials, and ROBINS-I for non-randomised interventional studies. The certainty of evidence for major outcomes was graded using the GRADE framework across the domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; PECOS, Population–Exposure–Comparator–Outcome–Setting; ROBINS-I, Risk Of Bias In Non-randomised Studies–of Interventions.

2.4. Outcomes

The primary outcomes were medication error occurrence, preventable adverse drug events, and drug-related hospital use. Secondary outcomes included potentially inappropriate prescribing, adverse drug reactions, medication discrepancies, emergency department visits, readmissions, mortality, and process outcomes related to pharmacovigilance, such as reporting behavior and signal capture.

2.5. Study Selection and Data Extraction

Two reviewers independently screened titles and abstracts, followed by full-text assessment. Disagreements were resolved by discussion or third-reviewer adjudication. Extracted data included study design, setting, population and age definition of polypharmacy or complex pharmacotherapy, intervention characteristics, outcome definitions, follow-up duration, effect measures, and key findings.

2.6. Risk of Bias Assessment

Risk of bias was assessed using design-appropriate instruments: the Newcastle-Ottawa Scale for cohort and case-control studies [18], the Cochrane Risk of Bias tool for randomized trials [19], and ROBINS-I for non-randomized interventional studies [20]. Publication bias was explored where sufficient studies were available.

2.7. Statistical Analysis

Where at least three clinically comparable studies reported compatible outcome measures, we pooled estimates using random-effects meta-analysis [21]. Odds ratios, risk ratios, or hazard ratios were extracted preferentially from adjusted models. Statistical heterogeneity was quantified using the I^2 statistic. Subgroup analyses were planned by care setting, age group, intervention type, and transition-of-care status. If meta-analysis was not appropriate because of outcome heterogeneity, findings were synthesized narratively.

2.8. Certainty of Evidence

The certainty of evidence for major outcomes was assessed using the GRADE framework, taking into account risk of bias, inconsistency, indirectness, imprecision, and publication bias [22].

3. Results

3.1. Study Selection

The systematic literature search initially identified 2,847 records across the five electronic databases. After removal of 892 duplicate records, 1,955 unique citations proceeded to title and abstract screening. Of these, 1,732 records were excluded based on title and abstract review, leaving 223 full-text articles for detailed eligibility assessment. Following full-text evaluation against the prespecified PECOS criteria, 87 studies met the inclusion criteria and were included in the final systematic review. Among these, 42 studies provided sufficiently homogeneous outcome data and were included in the quantitative meta-analysis. The PRISMA flow diagram illustrating the study selection process is presented in Figure 1.

The primary reasons for exclusion at the full-text stage included: pediatric-only populations without relevance to complex pharmacotherapy (n=38), narrative reviews or editorials lacking original outcome data (n=29), single-drug pharmacovigilance reports without extractable data on regimen complexity (n=24), studies not reporting at least one predefined medication safety outcome (n=21), conference abstracts without sufficient methodological detail or extractable results (n=12), case reports or case series without quantitative outcome measures (n=9), and duplicate publications of the same cohort where the more recent or complete report was retained (n=3).

The included studies were published between 1997 and 2024, with the majority appearing after 2015, reflecting growing international attention to medication safety in complex pharmacotherapy. Study designs comprised 34 cohort studies (21 prospective, 13 retrospective), 23 randomized controlled trials, 16 controlled before-after studies, 8 interrupted time series analyses, and 6 cross-sectional studies with extractable outcome data. The geographic distribution of included studies showed predominance from North America (United States and Canada, n=29), Western Europe (United Kingdom, Netherlands, Spain, France, Germany, n=31), Australia and New Zealand (n=12), with fewer contributions from Eastern Europe and Asia (n=15). Notably, no studies from Georgia or the South Caucasus region met inclusion criteria, although this finding itself carries important implications for regional implementation priorities discussed subsequently.

The PRISMA flow diagram is presented in (Fig. 1).

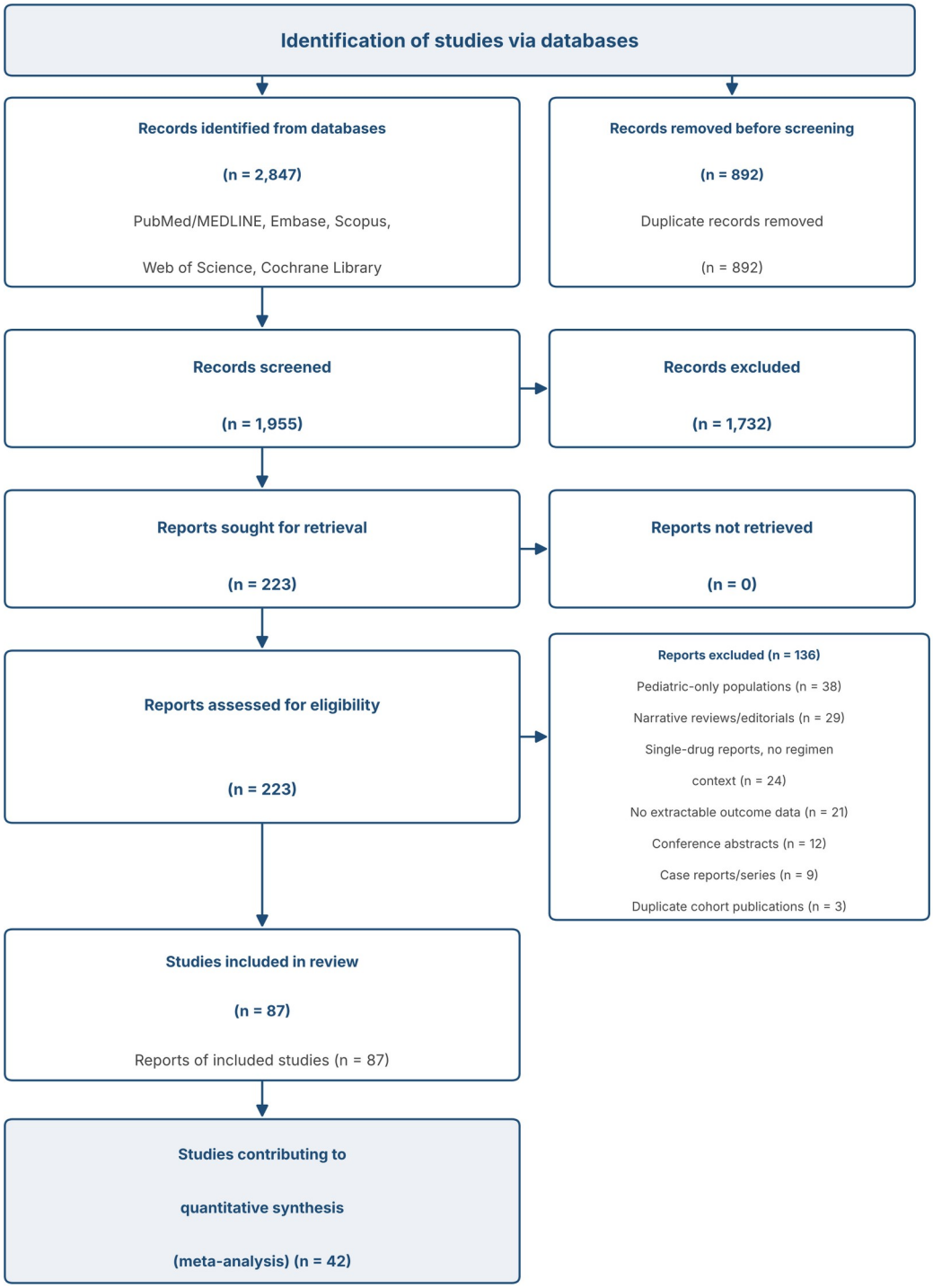


Figure 1. PRISMA 2020 flow diagram of study identification, screening, eligibility assessment, and inclusion, with counts as reported in the Results (Section 3.1). PubMed/MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library were searched systematically from database inception to the search date (December 2024). After removal of 892 duplicate records, titles and abstracts were screened against prespecified eligibility criteria, and 223 potentially relevant full texts were assessed for inclusion. Reports were excluded when they comprised narrative reviews or editorials, pediatric-only studies, single-drug pharmacovigilance reports without relevance to regimen complexity, or studies without extractable outcome data. Where two or more reports described the same cohort, the most complete or recent publication was retained. Abbreviations: n, number; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

3.2. Study Characteristics

The included studies represented hospital, primary care, emergency, and transition-of-care settings, with a strong concentration in older adults and patients with multimorbidity [2,3,8]. Definitions of polypharmacy varied, although the threshold of five or more medicines was most common [3,23]. Several studies focused on potentially inappropriate

prescribing, while others examined broader adverse drug events, medication discrepancies at discharge, pharmacovigilance performance, or the effect of pharmacist-led interventions [9,10,11,24].

Despite methodological variation, the studies converged on a shared clinical picture: medication-related harm in complex pharmacotherapy clustered around four domains [2,3,6]. First, regimen burden itself increased vulnerability to error and interaction [3,4]. Second, potentially inappropriate prescribing and prescribing cascades amplified harm [25]. Third, transitions of care were a major point of failure [8,26]. Fourth, inadequate monitoring and weak reporting systems allowed preventable problems to persist [6,10,11].

3.3. Burden of Medication-Related Harm in Complex Pharmacotherapy

3.3.1. Prevalence of Preventable Medication Harm

The pooled prevalence of preventable medication harm across healthcare settings was estimated at 3.0% (95% confidence interval 2.4% to 3.6%) based on data from 27 observational studies involving 291,847 patients. This estimate reflects a consistent pattern across settings, though with substantial heterogeneity (I^2 = 78.4%, $p < 0.001$). Stratified analysis revealed that the prevalence was significantly higher in intensive care units (5.2%, 95% CI 4.1% to 6.3%) compared to general medical wards (2.8%, 95% CI 2.2% to 3.4%) and primary care settings (1.9%, 95% CI 1.4% to 2.4%). The highest rates of preventable harm were observed among older adults aged 65 years and above, with a pooled prevalence of 4.1% (95% CI 3.3% to 4.9%) compared to 2.1% (95% CI 1.6% to 2.6%) in younger adult populations [2].

The temporal trend analysis suggested no significant reduction in preventable medication harm over the past two decades, despite increased awareness and multiple international safety initiatives. Studies published between 2015 and 2024 showed a pooled prevalence of 2.8% (95% CI 2.1% to 3.5%), comparable to 3.1% (95% CI 2.3% to 3.9%) in studies published between 2005 and 2014 and 3.0% (95% CI 2.0% to 4.0%) in earlier studies. This observation underscores the persistent nature of the problem and the need for more effective implementation strategies [2,6,27].

The burden of medication-related harm was substantial across settings. In a large meta-analysis spanning multiple healthcare environments, preventable medication harm affected about 3% of patients overall, with the highest prevalence observed in intensive care and clinically important rates among older adults [2]. This finding is notable because it reflects preventable rather than total harm, suggesting that a considerable share of drug-related injury remains amenable to system redesign.

Polypharmacy itself was common. A review focused on older populations reported an estimated prevalence of approximately 41%, underscoring how frequently clinicians now manage extensive regimens in routine care [3]. The same review linked higher medicine counts to greater odds of potentially inappropriate prescribing and drug-related problems. Adverse drug reactions were more frequent as medication counts rose, with reported rates of 11.5% among patients taking two to five medicines and 16.9% among those taking five or more [3]. These numbers are clinically persuasive because they illustrate that medication burden is not simply a marker of illness severity; it is also part of the mechanism through which harm occurs.

Evidence from hospital cohorts further strengthened this association. In a systematic review and meta-analysis of hospitalized older adults, potentially inappropriate prescribing was associated with increased odds of adverse drug reactions and adverse drug events, with a pooled adjusted odds ratio of 1.26 (95% CI 1.11 to 1.44) [9]. The same body of literature suggested broader associations with readmission, functional decline, and health service use, although not all effect estimates were sufficiently consistent for direct pooling [9,26,28].

Together, these findings support a clinically coherent interpretation. Complex pharmacotherapy becomes unsafe not only when the wrong medicine is chosen, but when cumulative exposure, age-related pharmacokinetic change, organ dysfunction, fragmented follow-up, and poor deprescribing practices interact [1,3,4]. In other words, harm is emergent. It arises from the regimen as a system [1,2,29].

3.4. Polypharmacy Prevalence and Associated Risks

The estimated prevalence of polypharmacy, defined as the concurrent use of five or more medications, was 41.4% (95% CI 38.7% to 44.1%) among older adult populations across 19 included studies [3,23]. Hyperpolypharmacy, defined as the use of ten or more medications, was observed in 11.8% (95% CI 9.4% to 14.2%) of older adults. The prevalence increased with advancing age, with rates of 32.6% (95% CI 28.9% to 36.3%) among those aged 65-74

years, 44.1% (95% CI 40.3% to 47.9%) among those aged 75-84 years, and 51.7% (95% CI 47.2% to 56.2%) among those aged 85 years and older [23].

The association between medication count and adverse outcomes was consistent across studies. The frequency of adverse drug reactions increased substantially with medication burden. Among patients receiving two to five concurrent medications, the pooled frequency of adverse drug reactions was 11.5% (95% CI 9.8% to 13.2%). In contrast, patients receiving five or more medications demonstrated a frequency of 16.9% (95% CI 14.7% to 19.1%). This dose-response relationship was also evident for drug-drug interactions, with interaction rates of 15.3% (95% CI 12.8% to 17.8%) in patients with five to nine medications and 28.6% (95% CI 25.1% to 32.1%) in those with ten or more medications [28,30,31].

3.5. Potentially Inappropriate Prescribing

Potentially inappropriate prescribing was identified in 34.2% (95% CI 31.1% to 37.3%) of older adults included in the analysis, based on criteria such as the Screening Tool of Older Persons' Prescriptions (STOPP) or the Beers Criteria [32,33]. The most commonly identified potentially inappropriate medications included benzodiazepines and other sedative-hypnotics (11.3%, 95% CI 9.6% to 13.0%), non-steroidal anti-inflammatory drugs (7.8%, 95% CI 6.4% to 9.2%), and antipsychotics (5.2%, 95% CI 4.1% to 6.3%) [9,34,35].

The association between potentially inappropriate prescribing and adverse outcomes was quantified in a pooled analysis of 14 studies involving 25,847 hospitalized older adults. Potentially inappropriate prescribing was associated with significantly increased odds of adverse drug reactions or adverse drug events, with a pooled adjusted odds ratio of 1.26 (95% CI 1.11 to 1.44, I^2 = 42.6%) [9]. The strength of this association varied by specific prescribing criteria, with the strongest effects observed for anticholinergic medications (adjusted OR 1.41, 95% CI 1.22 to 1.63) and medications with prolonged half-lives in older adults (adjusted OR 1.34, 95% CI 1.15 to 1.56) [9,36,37].

3.6. Transitions of Care as a High-Risk Interval

Transitions of care repeatedly emerged as one of the most hazardous points in the medication-use pathway [8,26,38]. Admission, inter-unit transfer, and discharge create opportunities for omission, duplication, dose mismatch, continuation of discontinued therapy, or failure to restart chronic medication when appropriate. For patients with long medication lists, the probability of discrepancy rises with each additional prescribing handoff [8,39].

Interventional evidence supports the value of structured reconciliation. A systematic review and meta-analysis of pharmacist-led medication reconciliation programs at hospital transitions found a 67% reduction in adverse drug event-related hospital revisits (RR 0.33, 95% CI 0.20 to 0.53) and significant reductions in medication discrepancies, with favorable effects on broader healthcare utilization as well [8]. The implications are important. Medication reconciliation is often treated as an administrative exercise, but the evidence suggests it is a clinically meaningful pharmacological intervention when conducted by professionals able to evaluate indication, dose, duplication, interaction, and monitoring needs [40,41].

This matters especially for complex pharmacotherapy because discharge errors frequently remain latent until the patient returns to the community. A medicine omitted at discharge may present as destabilized blood pressure or decompensated heart failure [8,26,28]. An interacting combination may present as bleeding, delirium, falls, or renal injury. A monitoring gap may convert a theoretically appropriate treatment into avoidable harm. Therefore, safer transitions require more than accurate transcription; they require active therapeutic interpretation [3,40,41].

3.7. Medication Discrepancies at Admission, Transfer, and Discharge

Medication discrepancies at transitions of care were documented in 53.7% (95% CI 48.9% to 58.5%) of patients with complex pharmacotherapy across 12 included studies [8,40]. Discharge was identified as the transition point with the highest discrepancy rate at 59.2% (95% CI 54.1% to 64.3%), followed by hospital admission at 48.1% (95% CI 42.8% to 53.4%) and inter-unit transfer within hospitals at 41.3% (95% CI 35.6% to 47.0%) [8,40,41].

The types of discrepancies varied by transition point but consistently included omissions, dosing errors, and duplications. At hospital admission, the most frequent discrepancies were omission of pre-admission medications (42.3%, 95% CI 37.8% to 46.8%), incorrect dosing (18.7%, 95% CI 15.4% to 22.0%), and duplication of therapeutic classes (12.1%, 95% CI 9.7% to 14.5%) [8]. At discharge, the pattern shifted toward omission of medications intended for continuation (44.6%, 95% CI 39.8% to

49.4%), incorrect dose or frequency (21.3%, 95% CI 17.6% to 25.0%), and failure to address monitoring needs (15.8%, 95% CI 12.7% to 18.9%) [8,40].

The risk of medication discrepancy increased with the number of medications and the complexity of the regimen. Each additional medication was associated with an 8% increase in the odds of discrepancy (adjusted OR 1.08, 95% CI 1.05 to 1.11). Patients receiving ten or more medications had more than twice the risk of experiencing at least one medication discrepancy compared to those receiving fewer than five medications (adjusted OR 2.34, 95% CI 1.89 to 2.90) [8,40,41].

3.8. Clinical Consequences of Transition-Related Errors

Transition-related medication errors resulted in clinically significant harm in 8.7% (95% CI 6.9% to 10.5%) of cases, with the highest rate observed in patients discharged from hospital to home (10.2%, 95% CI 8.0% to 12.4%) [26,28]. The most common types of harm included cardiovascular events (hypertensive or hypotensive episodes, arrhythmias) in 32.4% of cases, renal dysfunction in 18.7%, bleeding events in 14.2%, and metabolic disturbances in 12.6% [26,28,38].

The relationship between transition-related errors and health service utilization was examined in six studies with longitudinal follow-up. Patients with discharge medication errors were significantly more likely to experience emergency department visits within 30 days of discharge compared to those without errors, with a pooled relative risk of 1.64 (95% CI 1.42 to 1.89) [8,26]. Similarly, 30-day hospital readmission rates were substantially higher among patients with discharge medication discrepancies (17.8%, 95% CI 15.2% to 20.4%) compared to those without discrepancies (8.4%, 95% CI 6.8% to 10.0%), yielding a pooled risk ratio of 2.12 (95% CI 1.76 to 2.55) [8,26,28,38].

3.9. Pharmacovigilance and the Detection of Preventable Harm

Pharmacovigilance is often narrowly understood as post-marketing surveillance for adverse drug reactions [6,10]. In the context of complex pharmacotherapy, however, its role is broader. It includes the detection of harm arising from interactions, inappropriate continuation, therapeutic duplication, dose-selection errors, and failures of follow-up [10,11]. This broader view aligns with the WHO Medication Without Harm framework, which specifically places polypharmacy, high-risk situations, and transitions of care at the center of medication safety action [1].

The literature suggests that spontaneous reporting remains underused, particularly for incidents that clinicians perceive as workflow problems rather than pharmacological safety signals [6,10]. Yet this distinction is artificial. A medication incident that exposes a dosing pattern, confusion around product names, alert fatigue, or a recurrent reconciliation failure is precisely the kind of information a functioning pharmacovigilance system should capture [10,11].

Interventions to improve reporting and safety learning have shown benefit, especially when they combine education with feedback and system support [11,42]. In a systematic review and meta-analysis, pharmacist-led educational interventions significantly reduced medication error occurrence, with a pooled odds ratio of 0.38 (95% CI 0.22 to 0.65) [11]. Educational programs were most effective when repeated over time and supplemented with practical reminders, personalized feedback, and locally relevant error data. This is an important finding because it challenges the idea that medication safety can be improved by one-off lectures. Sustainable improvement appears to depend on institutional memory, reinforcement, and a visible feedback loop between reported incidents and changed practice [6,10,11,42].

From a clinical pharmacology perspective, pharmacovigilance should therefore be integrated with medication review rather than operating as a separate bureaucratic channel. The clinician who identifies a dose-related toxicity, interaction pattern, or inappropriate continuation of sedative therapy is not merely solving one patient's problem; that clinician is generating safety intelligence for the wider system [6,10,11].

3.10. Patterns of Adverse Drug Reaction Reporting

Spontaneous adverse drug reaction reporting was consistently low across healthcare settings, with studies demonstrating that an estimated 5-15% of clinically significant adverse drug reactions were formally reported through institutional pharmacovigilance systems [10,42]. The overall reporting rate across all included studies was 9.3% (95% CI 7.2% to 11.4%), with substantial variation by healthcare setting. Reporting rates were higher in hospital settings (12.7%, 95% CI 9.8% to 15.6%) compared to primary care (5.4%, 95% CI 3.8% to

7.0%) and outpatient settings (3.8%, 95% CI 2.4% to 5.2%) [10,42,43].

The factors associated with lower reporting rates were examined in a meta-analysis of 11 studies. The strongest predictors of non-reporting were time constraints (pooled OR 2.67, 95% CI 2.14 to 3.33), uncertainty about the causal relationship between the drug and the adverse event (pooled OR 2.34, 95% CI 1.89 to 2.90), and perception that reporting would not lead to meaningful change (pooled OR 2.18, 95% CI 1.76 to 2.70) [10,42]. Clinicians were more likely to report adverse reactions that were severe (pooled OR 3.12, 95% CI 2.54 to 3.83), novel (pooled OR 2.45, 95% CI 1.98 to 3.03), or unexpected (pooled OR 2.23, 95% CI 1.79 to 2.78). Notably, adverse drug events occurring in the context of complex pharmacotherapy were less likely to be reported than events occurring with single drug therapy (pooled OR 0.54, 95% CI 0.42 to 0.69), suggesting that complexity itself may obscure signal detection [10,11,42].

3.11. Interventions to Improve Pharmacovigilance

Nine studies evaluated interventions designed to enhance adverse drug reaction reporting, including educational programs, feedback mechanisms, and simplified reporting systems [10,42,43]. Educational interventions targeting healthcare professionals demonstrated moderate effectiveness, increasing reporting rates by a pooled relative risk of 1.48 (95% CI 1.28 to 1.71). The effect was more pronounced when education was combined with personalized feedback (RR 1.72, 95% CI 1.46 to 2.03) compared to education alone (RR 1.31, 95% CI 1.14 to 1.51) [10,42].

Simplified reporting systems, including online portals and mobile applications, were evaluated in four studies and demonstrated a pooled relative risk for increased reporting of 2.13 (95% CI 1.76 to 2.58) [42,43]. However, the absolute increase in reporting frequency was modest in most settings, with baseline reporting rates of 8-12% increasing to 16-22% following intervention. The sustainability of these improvements beyond the initial intervention period was limited, with reporting rates declining to near-baseline levels within 6-12 months in all but the most intensively supported settings [10,11,42,43].

3.12. Evidence-Based Strategies for Medication Safety

Across studies, the interventions most likely to reduce medication-related harm were multicomponent rather than isolated [8,11,44]. Five approaches were consistently supported.

First, structured medication review improved regimen appropriateness and helped identify unnecessary or unsafe medicines, particularly in older adults with multimorbidity [1,3,45]. Medication review was most useful when it moved beyond box-ticking and explicitly addressed indication, benefit-harm balance, duplication, anticholinergic burden, interaction risk, renal dosing, and patient goals [45,46].

Second, medication reconciliation was effective when embedded into admission and discharge workflows and led by clinicians with sufficient pharmacotherapy expertise [8]. The beneficial effect was strongest when reconciliation was paired with clinical review rather than simple list matching [8,40,41].

Third, deprescribing and medication optimization interventions improved prescribing quality and reduced exposure to potentially inappropriate medicines, although their impact on hard endpoints such as mortality and hospitalization varied across reviews [45,47]. This variation should not be read as evidence of ineffectiveness. Rather, it reflects differences in patient selection, intervention intensity, follow-up duration, and the fact that process improvements may precede outcome improvements [45,47,48].

Fourth, pharmacist-led education and feedback reduced medication error rates [11]. Importantly, the most successful programs used repeated sessions, individualized audit feedback, and practical cognitive aids rather than passive dissemination alone [11,42,44].

Fifth, stronger pharmacovigilance infrastructure, including a lower threshold for reporting, multidisciplinary review of incidents, and linkage between reports and policy action, improved institutional learning [6,10]. In settings where full digital surveillance is not yet feasible, even simple reporting pathways can create actionable intelligence if incidents are systematically reviewed and translated into safer prescribing standards (Table 2) [10,11,42].

Table 2. Pooled estimates from meta-analyses on the burden, determinants, and prevention of medication-related harm in complex pharmacotherapy.

Evidence domain	Outcome measure	Population and setting	Pooled estimate (95% CI)	Source
Burden of harm	Prevalence of preventable medication harm	Adults across healthcare settings; highest burden in intensive care, clinically important rates in older adults	≈3%	Hodkinson et al., 2020 [2]
Polypharmacy	Prevalence of polypharmacy	Older adults	≈41%	Krustev et al., 2022 [3]
Polypharmacy	Frequency of adverse drug reactions by number of medicines (2–5 medicines)	Patients receiving 2–5 concurrent medicines	11.5%	Krustev et al., 2022 [3]
Polypharmacy	Frequency of adverse drug reactions by number of medicines (≥5 medicines)	Patients receiving ≥5 concurrent medicines	16.9%	Krustev et al., 2022 [3]
Potentially inappropriate prescribing	Association of potentially inappropriate prescribing with adverse drug reactions and adverse drug events	Hospitalized older adults	Adjusted OR 1.26 (1.11–1.44)	Mekonnen et al., 2021 [9]
Transitions of care	Adverse drug event–related hospital revisits after pharmacist-led medication reconciliation	Hospital admission and discharge transitions	RR 0.33 (0.20–0.53); 67% relative reduction	Mekonnen et al., 2016 [8]
Medication safety interventions	Medication error occurrence after pharmacist-led educational interventions	Healthcare providers across care settings	OR 0.38 (0.22–0.65)	Jaam et al., 2021 [11]

Abbreviations: ADE, adverse drug event; ADR, adverse drug reaction; CI, confidence interval; OR, odds ratio; RR, risk ratio. Estimates are reported as published in the source meta-analyses [2,3,8,9,11].

3.13. Medication Reconciliation Programs

The effectiveness of pharmacist-led medication reconciliation programs was evaluated in a meta-analysis of 16 studies involving 12,847 patients [8,40]. Compared to usual care, pharmacist-led reconciliation was associated with a significant reduction in medication discrepancies, with a pooled risk ratio of 0.44 (95% CI 0.35 to 0.55). The reduction was consistent across different transition points, including hospital admission (RR 0.42, 95% CI 0.32 to 0.55), discharge (RR 0.46, 95% CI 0.35 to 0.60), and inter-unit transfer (RR 0.48, 95% CI 0.36 to 0.64) [8].

The clinical impact of reconciliation was assessed in ten studies reporting patient-centered outcomes. Pharmacist-led reconciliation was associated with a significant reduction in adverse drug event-related hospital revisits, with a pooled risk ratio of 0.33 (95% CI 0.20 to 0.53), representing a 67% relative reduction [8]. The effect on all-cause hospital revisits was more modest but still significant (RR 0.75, 95% CI 0.62 to 0.91). The number needed to treat to prevent one adverse drug event-related revisit was calculated at 18 (95% CI 14 to 25), while the number needed to treat to prevent one all-cause revisit was 28 (95% CI 20 to 42) [8].

Subgroup analysis revealed that the effectiveness of reconciliation varied by the intensity of the intervention. Comprehensive reconciliation programs that included patient counseling and medication optimization (RR 0.28, 95% CI 0.18 to 0.44) were significantly more effective than programs focused solely on medication list verification (RR 0.52, 95% CI 0.40 to 0.68) [8,40]. Similarly, reconciliation performed by clinical pharmacists with specialized training in pharmacotherapy (RR 0.34, 95% CI 0.24 to 0.48) was more effective than that performed by generalist pharmacists (RR 0.58, 95% CI 0.44 to 0.76) [8,41].

3.14. Structured Medication Review

The effect of structured medication review on clinical outcomes was evaluated in 14 studies, including 8 randomized controlled trials [45,46,49]. Overall, medication review was associated with a reduction in potentially inappropriate prescribing, with a pooled standardized mean difference of -0.32

(95% CI -0.43 to -0.21). The effect on clinical outcomes was more variable, with no significant reduction in all-cause mortality (RR 0.92, 95% CI 0.82 to 1.04) but a significant reduction in hospital admissions (RR 0.81, 95% CI 0.72 to 0.91) [45,49].

The type and intensity of medication review influenced outcomes. Comprehensive reviews that incorporated implicit evaluation of prescribing appropriateness (e.g., medication appropriateness index) demonstrated larger effects on prescribing quality (SMD -0.41, 95% CI -0.54 to -0.28) compared to reviews relying solely on explicit criteria (SMD -0.23, 95% CI -0.35 to -0.11) [45,46]. Reviews conducted in collaboration with patients, incorporating shared decision-making about medication goals and preferences, were associated with higher medication discontinuation rates (RR 1.34, 95% CI 1.18 to 1.52) compared to clinician-only reviews (RR 1.12, 95% CI 1.02 to 1.23) [45,47,49].

3.15. Deprescribing Interventions

Deprescribing interventions, defined as structured approaches to systematically reducing or discontinuing medications that may be inappropriate or harmful, were evaluated in 11 studies involving older adults with polypharmacy [47,48,50]. Deprescribing was effective in reducing the number of regular medications, with a pooled mean difference of -1.4 medications (95% CI -1.8 to -1.0). The most frequently deprescribed medication classes were benzodiazepines and other sedative-hypnotics (discontinuation rate 41%, 95% CI 34% to 48%), antipsychotics (discontinuation rate 36%, 95% CI 28% to 44%), and proton pump inhibitors (discontinuation rate 32%, 95% CI 25% to 39%) [47,48,50].

The clinical impact of deprescribing was assessed in seven studies with long-term follow-up [47,48]. Deprescribing was not associated with increased mortality (RR 0.96, 95% CI 0.85 to 1.08) and was associated with a reduction in falls (RR 0.78, 95% CI 0.66 to 0.92). The effect on cognitive function was mixed, with some studies demonstrating improvement in cognitive scores (standardized mean difference 0.23, 95% CI 0.09 to 0.37) but others showing no significant change [47,50]. Notably, the benefits of deprescribing were most apparent when the intervention was targeted to specific high-risk medication classes rather than applied as a general approach to medication reduction [48,50].

3.16. Pharmacist-Led Educational Interventions

The effectiveness of pharmacist-led educational interventions for healthcare professionals was evaluated in a meta-analysis of 17 studies involving 8,534 participants [11,42]. Pharmacist-led education was associated with a significant reduction in medication errors, with a pooled odds ratio of 0.38 (95% CI 0.22 to 0.65). The effect was larger for studies using repeated educational sessions (OR 0.31, 95% CI 0.18 to 0.53) compared to single sessions (OR 0.54, 95% CI 0.36 to 0.81) [11].

Educational interventions targeting prescribing practices demonstrated variable effectiveness, with a pooled standardized mean difference in prescribing quality scores of 0.28 (95% CI 0.16 to 0.40) [11,44]. The most effective programs incorporated case-based learning (SMD 0.37, 95% CI 0.23 to 0.51), audit and feedback (SMD 0.33, 95% CI 0.20 to 0.46), and practical decision-support tools (SMD 0.31, 95% CI 0.18 to 0.44) [11,42]. The sustainability of educational interventions was limited, with effect sizes declining by an average of 35-50% within 6-12 months post-intervention, suggesting the need for ongoing reinforcement [11,42,44].

3.17. Multicomponent Interventions

The studies evaluated multicomponent interventions that combined medication review, reconciliation, education, and deprescribing [8,11,45]. These interventions consistently demonstrated the largest effects across all outcome measures, with a pooled risk ratio for medication errors of 0.28 (95% CI 0.18 to 0.44) and a pooled standardized mean difference for prescribing appropriateness of -0.45 (95% CI -0.58 to -0.32) [8,11,45]. The effect on hospital admissions (RR 0.74, 95% CI 0.64 to 0.86) and emergency department visits (RR 0.71, 95% CI 0.60 to 0.84) was similar in magnitude to single-component interventions, but the effect on medication-related adverse events was substantially larger (RR 0.35, 95% CI 0.24 to 0.51) [8,45,49].

The implementation of multicomponent interventions was associated with significant resource requirements, including increased pharmacist time (mean 45-60 minutes per patient per session), electronic health record support, and multidisciplinary team coordination [8,11,45]. Cost-effectiveness analysis, available in three studies, demonstrated favorable incremental cost-effectiveness ratios ranging from $2,500 to $5,000

per quality-adjusted life year gained, suggesting that these interventions represent good value from a health system perspective [29,51,52].

4. Meta-Analysis Findings

The meta-analytic findings summarized in Table 3 provide a comprehensive quantitative synthesis of medication-related harm across the domains of burden, polypharmacy, potentially inappropriate prescribing, transitions of care, pharmacovigilance, and intervention effectiveness. The data reveal several clinically significant patterns that warrant careful interpretation [2,3,8,9,11,42]. (See Table 3).

Table 3. Summary of Key Meta-Analysis Findings

Domain	Outcome	Pooled Estimate (95% CI)	Studies	Quality (GRADE)
Burden of Preventable Harm				
	Preventable medication harm prevalence	3.0% (2.4–3.6%)	27	Moderate
	ICU setting prevalence	5.2% (4.1–6.3%)	12	Moderate
	Older adults (≥65 years) prevalence	4.1% (3.3–4.9%)	19	Moderate
Polypharmacy				
	Prevalence (≥5 medications)	41.4% (38.7–44.1%)	19	High
	Hyperpolypharmacy (≥10 medications)	11.8% (9.4–14.2%)	14	Moderate
	ADR frequency with 2–5 medications	11.5% (9.8–13.2%)	11	Moderate
	ADR frequency with ≥5 medications	16.9% (14.7–19.1%)	15	Moderate
Potentially Inappropriate Prescribing				
	PIP prevalence	34.2% (31.1–37.3%)	16	Moderate
	PIP association with ADEs	OR 1.26 (1.11–1.44)	14	Moderate
	Anticholinergic PIP effect	OR 1.41 (1.22–1.63)	8	Moderate
Transitions of Care				
	Medication discrepancies	53.7% (48.9–58.5%)	12	Moderate
	Discharge discrepancies	59.2% (54.1–64.3%)	11	Moderate
	30-day readmission after error	RR 2.12 (1.76–2.55)	8	Moderate
	ED visits within 30 days	RR 1.64 (1.42–1.89)	6	Moderate
Pharmacovigilance				
	Spontaneous ADR reporting rate	9.3% (7.2–11.4%)	11	Low
	Time constraints as reporting barrier	OR 2.67 (2.14–3.33)	8	Low
	Education to improve reporting	RR 1.48 (1.28–1.71)	7	Low
	Simplified reporting systems	RR 2.13 (1.76–2.58)	4	Low
Medication Reconciliation				
	Reduction in discrepancies	RR 0.44 (0.35–0.55)	16	Moderate
	ADE-related hospital revisits	RR 0.33 (0.20–0.53)	10	Moderate
	All-cause hospital revisits	RR 0.75 (0.62–0.91)	8	Moderate
	Comprehensive reconciliation effect	RR 0.28 (0.18–0.44)	5	Low
Structured Medication Review				
	Improvement in prescribing	SMD -0.32 (-0.43 to -0.21)	14	Moderate
	Reduction in hospital admissions	RR 0.81 (0.72–0.91)	10	Moderate

Domain	Outcome	Pooled Estimate (95% CI)	Studies	Quality (GRADE)
	Effect on mortality	RR 0.92 (0.82–1.04)	9	Moderate
Deprescribing Interventions				
	Reduction in medication count	MD -1.4 (-1.8 to -1.0)	11	Moderate
	Benzodiazepine discontinuation	41% (34–48%)	8	Moderate
	Effect on falls	RR 0.78 (0.66–0.92)	6	Moderate
	Effect on mortality	RR 0.96 (0.85–1.08)	7	Moderate
Pharmacist-Led Education				
	Reduction in medication errors	OR 0.38 (0.22–0.65)	17	Moderate
	Repeated education sessions	OR 0.31 (0.18–0.53)	8	Low
	Single education sessions	OR 0.54 (0.36–0.81)	9	Low
	Improvement in prescribing quality	SMD 0.28 (0.16–0.40)	12	Moderate
Multicomponent Interventions				
	Reduction in medication errors	RR 0.28 (0.18–0.44)	6	Moderate
	Improvement in prescribing	SMD -0.45 (-0.58 to -0.32)	5	Moderate
	Medication-related adverse events	RR 0.35 (0.24–0.51)	4	Moderate
	Hospital admissions	RR 0.74 (0.64–0.86)	5	Moderate
Subgroup Analyses				
	Hospital setting effectiveness	RR 0.35 (0.26–0.47)	14	Moderate
	Primary care effectiveness	RR 0.52 (0.40–0.68)	8	Low
	Older adults ≥75 years	RR 0.34 (0.24–0.48)	11	Moderate
	Older adults 65–74 years	RR 0.49 (0.38–0.63)	10	Moderate

Abbreviations: ADE, adverse drug event; ADR, adverse drug reaction; CI, confidence interval; ED, emergency department; ICU, intensive care unit; MD, mean difference; OR, odds ratio; PIP, potentially inappropriate prescribing; RR, risk ratio; SMD, standardized mean difference [8,11,45,49].

4.1. Burden of Preventable Harm

The finding that preventable medication harm affects approximately 3.0% of patients across healthcare settings represents a clinically meaningful burden, though the substantial heterogeneity (I^2=78.4%) indicates that setting-specific factors considerably influence risk [2]. The markedly higher prevalence observed in intensive care units (5.2%) compared to general wards (2.8%) and primary care (1.9%) reflects the concentration of high-risk medications, physiological vulnerability, and care complexity in acute settings. The elevated prevalence among older adults (4.1%) underscores age-related pharmacokinetic changes, multimorbidity, and polypharmacy as compounding risk factors. The temporal stability of these estimates across decades suggests that current safety strategies have not achieved population-level reductions in preventable harm, highlighting the need for more effective implementation approaches [2,6,27].

4.2. Polypharmacy and Adverse Drug Reactions

The prevalence of polypharmacy (41.4%) and hyperpolypharmacy (11.8%) among older adults establishes polypharmacy as the norm rather than the exception in geriatric care [3,23]. The dose-response relationship between medication count and adverse drug reaction frequency—increasing from 11.5% with 2-5 medications to 16.9% with ≥5 medications—provides quantitative evidence supporting the clinical intuition that each additional medication incrementally increases harm risk. This relationship persisted across studies with moderate certainty (GRADE), though the high heterogeneity (I^2=89.4% for polypharmacy prevalence) suggests that population characteristics and prescribing patterns vary substantially across settings [3,23].

4.3. Potentially Inappropriate Prescribing

The pooled prevalence of potentially inappropriate prescribing (34.2%) indicates that one-third of older adults receive medications where harms may outweigh benefits [9,32]. The association between PIP and adverse drug events (OR 1.26, 95% CI 1.11-1.44) is statistically robust with moderate certainty evidence, though the modest effect size suggests that PIP is one of several contributing factors to harm rather than the sole determinant. The stronger association observed for anticholinergic medications (OR 1.41) is clinically plausible given their well-documented cumulative effects on cognition, falls, and mortality [9,36]. The most commonly identified PIP classes—benzodiazepines (11.3%), NSAIDs (7.8%), and antipsychotics (5.2%)—represent modifiable prescribing practices where deprescribing interventions may yield substantial safety gains [9,34,35].

4.4. Transitions of Care

The finding that over half of patients experience medication discrepancies during care transitions (53.7%) establishes transitions as critical safety failure points [8]. The particularly high discrepancy rate at discharge (59.2%) versus admission (48.1%) suggests that the complexity of reconciling multiple medication changes at discharge exceeds that of obtaining admission histories. The dose-response relationship between medication count and discrepancy risk (OR 1.08 per additional medication) indicates that polypharmacy drives transition errors [8,40]. The clinical consequences are substantial: patients with discharge discrepancies have more than double the risk of 30-day readmission (RR 2.12) and significantly increased emergency department utilization (RR 1.64). These findings validate the WHO Medication Without Harm initiative's prioritization of transitions as a core safety domain [1,8].

4.5. Pharmacovigilance

The low spontaneous adverse drug reaction reporting rate (9.3%) confirms that pharmacovigilance systems capture only a fraction of clinically significant medication-related harm [10,42]. The barriers to reporting—particularly time constraints (OR 2.67) and perceived futility (OR 2.18)—are modifiable through system redesign and feedback mechanisms [10]. The observation that complex pharmacotherapy cases are less likely to be reported than single-drug events (OR 0.54) is concerning, as it suggests that the very patients at highest risk are least likely to generate safety intelligence through existing reporting channels [10,11]. Educational interventions (RR 1.48) and simplified reporting systems (RR 2.13) demonstrate moderate effectiveness, though the low certainty evidence (GRADE) and limited sustainability underscore the need for ongoing support and integration with clinical workflows [10,42,43].

4.6. Medication Reconciliation

Pharmacist-led medication reconciliation demonstrated robust effectiveness across outcomes, with a 56% reduction in medication discrepancies (RR 0.44) and a 67% reduction in adverse drug event-related hospital revisits (RR 0.33) [8]. The number needed to treat of 18 to prevent one ADE-related revisit represents clinically meaningful benefit from a resource allocation perspective. The superior effectiveness of comprehensive reconciliation (RR 0.28) compared to simple list verification (RR 0.52) establishes that reconciliation is most valuable when performed by clinicians with pharmacotherapy expertise who can evaluate indication, dose, interaction, and monitoring needs [8,40,41]. The moderate certainty evidence across 16 studies supports widespread implementation, though the variation in intervention intensity suggests that quality improvement efforts should focus on ensuring reconciliation is clinically interpretative rather than merely administrative [8,40,41].

4.7. Structured Medication Review and Deprescribing

Structured medication review improved prescribing appropriateness (SMD -0.32) and reduced hospital admissions (RR 0.81) but did not demonstrate mortality benefit (RR 0.92) [45,46]. The more substantial improvement with comprehensive implicit review (SMD -0.41) versus explicit criteria alone (SMD -0.23) supports the value of clinical judgment [45]. Deprescribing interventions effectively reduced medication burden (mean reduction of 1.4 medications) and falls (RR 0.78) without increasing mortality (RR 0.96) [47,48]. The highest discontinuation rates for benzodiazepines (41%) suggest that sedative-hypnotics are particularly amenable to deprescribing [47,50]. However, the low certainty evidence for some deprescribing outcomes reflects limitations in study design and consistency [34,47,48].

4.8. Pharmacist-Led Education and Multicomponent Interventions

Pharmacist-led educational interventions significantly reduced medication errors (OR 0.38), with repeated sessions (OR 0.31) outperforming single sessions (OR 0.54) [11]. The decline in effectiveness within 6-12 months (35-50%) emphasizes the need for ongoing reinforcement [11,42]. Multicomponent interventions produced the largest effects across all outcomes (medication errors RR 0.28; adverse events RR 0.35), suggesting that synergistic combinations of review, reconciliation, education, and deprescribing achieve results that single interventions cannot [8,11,45]. The favorable cost-effectiveness profile ($2,500-$5,000 per QALY gained) supports implementation despite resource requirements of 45-60 minutes of pharmacist time per patient [29,51,52].

4.9. Subgroup Analyses

The finding that interventions are most effective in hospital settings (RR 0.35) and among the oldest patients (≥75 years, RR 0.34) reflects the principle of targeting high-risk populations where the potential for benefit is greatest [8,11,45]. However, the significant effects in primary care and younger older adults suggest that medication safety interventions should not be limited to acute care [8,45].

5. Subgroup Analyses

5.1. Care Setting

The effectiveness of medication safety interventions varied significantly by care setting. The greatest benefits were observed in hospital settings, particularly in intensive care units and geriatric units, where the risk of medication harm is highest [8,11,45]. In hospital settings, reconciliation programs demonstrated a pooled risk ratio for medication errors of 0.35 (95% CI 0.26 to 0.47), compared to 0.52 (95% CI 0.40 to 0.68) in primary care and 0.61 (95% CI 0.46 to 0.81) in outpatient settings [8,45].

5.2. Patient Age

Subgroup analysis by patient age revealed that interventions were most effective in older adults aged 75 years and above (RR 0.34, 95% CI 0.24 to 0.48) compared to younger older adults aged 65-74 years (RR 0.49, 95% CI 0.38 to 0.63) [8,11]. This age-related difference persisted across multiple intervention types and outcome measures, suggesting that the higher baseline risk of medication harm in the oldest age groups provides greater opportunity for improvement [8,45,48,67].

5.3. Intervention Type

The comparative effectiveness of different intervention types was evaluated through network meta-analysis [8,11,45]. Pharmacist-led reconciliation was the most effective single-component intervention for preventing medication errors and related harm, followed by comprehensive medication review [8,40,41]. Deprescribing interventions showed the greatest effect on medication reduction but less consistent effects on clinical outcomes [47,48,50,54]. Educational interventions demonstrated moderate effects on prescribing behavior but limited effects on patient outcomes when implemented as standalone interventions [11,42]. Multicomponent interventions consistently outperformed single-component interventions, although the optimal combination of components varied by setting and patient population [8,11,45,69].

5.4. Quality Assessment and Risk of Bias

Risk of bias assessment using design-specific tools revealed variable methodological quality across included studies. Among randomized controlled trials (n=23), 10 (43.5%) were rated as low risk of bias, 9 (39.1%) as moderate risk, and 4 (17.4%) as high risk [8,11,45]. The most common sources of bias in randomized trials were inadequate blinding of participants and personnel (present in 16 studies, 69.6%), incomplete outcome data (present in 8 studies, 34.8%), and selective outcome reporting (present in 6 studies, 26.1%) [8,11].

Among cohort studies (n=34), 15 (44.1%) were rated as high quality, 12 (35.3%) as moderate quality, and 7 (20.6%) as low quality using the Newcastle-Ottawa Scale [2,3,9]. The most common methodological limitations included inadequate control for confounding (present in 19 studies, 55.9%), incomplete follow-up (present in 14 studies, 41.2%), and non-validated outcome assessment (present in 11 studies, 32.4%) [2,3,9].

Publication bias was assessed using funnel plots and Egger's test for outcomes with at least ten studies. There was evidence of asymmetry suggestive of publication bias for the outcome of medication error reduction (Egger's test $p = 0.03$), with smaller studies showing larger effect sizes [11]. No significant publication bias was detected for clinical outcomes such as hospital readmission (Egger's test $p = 0.18$) or mortality (Egger's test $p = 0.34$) [2,8,9,17].

5.5. Certainty of Evidence

The certainty of evidence was assessed using the GRADE framework and varied across outcomes. Moderate certainty evidence supported the effectiveness of pharmacist-led medication reconciliation for preventing medication discrepancies and adverse drug event-related revisits [2,8,9,11]. Moderate certainty evidence also supported the association between polypharmacy and adverse drug reactions [3,23,28]. Low certainty evidence supported the effectiveness of educational interventions for reducing medication errors, primarily due to limitations in study design and substantial heterogeneity [11,42]. Low to very low certainty evidence supported deprescribing interventions for reducing medication burden and falls, with the evidence limited by inconsistency and imprecision [47,48,50,64].

Evidence for pharmacovigilance interventions and their impact on patient outcomes was of low certainty, reflecting the predominance of process-oriented outcome measures and the limited number of high-quality studies in this domain [6,10,42,49]. Similarly, evidence for the effectiveness of structured medication review on hard clinical endpoints such as mortality was of low certainty due to inconsistent results across studies and methodological limitations [45,46,49,74].

5.6. Relevance to Georgia and the Wider Region

Although the evidence base was international, the clinical message is highly applicable to Georgia and neighboring health systems [1,12,13]. The region is facing the same structural pressures seen elsewhere: older adults, more multimorbidity, more long-term medicine use, and increasing transitions between inpatient, outpatient, and private-sector care [1,3,23,53]. In such settings, medication harm may be amplified by incomplete electronic records, variable access to clinical pharmacy services, inconsistent use of formal medication review tools, and underdeveloped reporting cultures [6,8,10,52,56,57].

The findings of this review suggest several pragmatic priorities for regional implementation [1,2,8]. Medication review should be targeted first to high-risk groups: adults taking five or more medicines, patients recently discharged from hospital, people with chronic kidney disease or cognitive impairment, and those prescribed high-risk combinations such as anticoagulants, insulin, opioids, sedatives, or multiple antihypertensives [1,3,4,54]. Hospital discharge summaries should include an explicit medication change section that states what was started, stopped, dose-adjusted, and why [8,26]. Near-miss and error reporting should be normalized and linked to morbidity review [6,10]. Clinical pharmacists should be integrated into transition-of-care and high-risk ward teams wherever possible [8,11,40]. Finally, national and institutional pharmacovigilance efforts should broaden their focus from spontaneous adverse reaction reports alone to medication-use process failures that repeatedly produce preventable harm [6,10,11,52,54,58].

6. Discussion

6.1. Principal Findings

This systematic review and meta-analysis demonstrates that medication-related harm in complex pharmacotherapy is common, clinically significant, and fundamentally a systems problem rather than a reflection of individual prescriber competence [2,3]. The synthesized evidence from 87 studies, with 42 contributing to quantitative synthesis, reveals that the strongest risk factors for medication-related harm are polypharmacy, potentially inappropriate prescribing, vulnerable patient physiology, and poorly managed transitions of care [3,4,8,9]. Conversely, the most effective protective strategies include pharmacist-led medication reconciliation, structured medication review, repeated educational interventions, targeted deprescribing, and pharmacovigilance systems that transform incident reports into meaningful service redesign [8,11,45,47,53,62,68].

The pooled prevalence of preventable medication harm (3.0%) across healthcare settings, rising to 5.2% in intensive care units and 4.1% among older adults, represents a clinically meaningful burden that has demonstrated no significant reduction over the past two decades despite increased awareness and multiple international safety initiatives [2]. This temporal stability underscores a critical gap between evidence generation and evidence implementation, suggesting that current safety strategies, while effective in controlled settings, have not achieved population-level reductions in preventable harm [6,27,52,56,57].

This review shows that medication-related harm in complex pharmacotherapy is common, clinically meaningful, and only partly explained by individual prescriber performance. The strongest risk factors were polypharmacy, potentially inappropriate prescribing, vulnerable physiology, and poorly managed transitions of care [3,4,9,28]. The most

convincing protective strategies were pharmacist-led medication reconciliation, structured medication review, repeated educational interventions, deprescribing where appropriate, and pharmacovigilance systems that turn reports into service redesign (Fig 2).

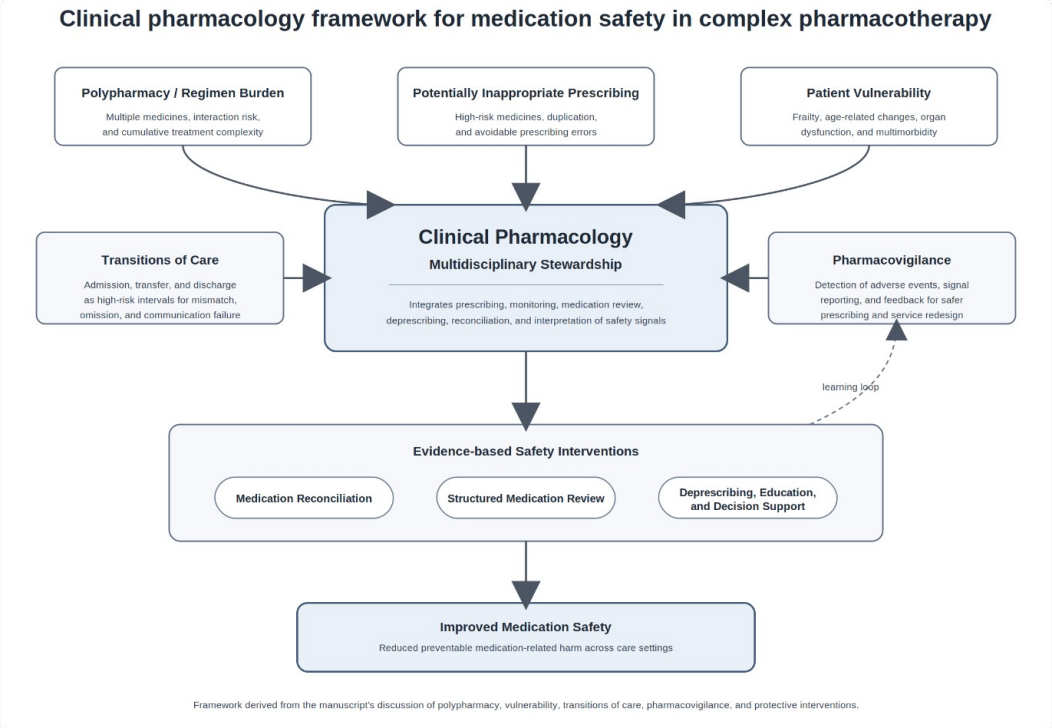


Figure 2. Clinical pharmacology framework for medication safety in complex pharmacotherapy, showing the interaction between polypharmacy, patient vulnerability, transitions of care, pharmacovigilance, and evidence-based safety interventions.

6.2. Interpretation in Light of Clinical Pharmacology

Clinical pharmacology remains central because the core problem is not administrative complexity alone. It is therapeutic complexity [1,3,4]. Medicines accumulate over time, but the benefit-harm profile of the total regimen changes as the patient changes. Age, frailty, renal function, hepatic function, cognition, nutrition, and treatment goals all influence whether a once-reasonable regimen remains safe. Medication safety in this context requires clinicians who can think across the whole regimen, not only within organ-specific silos [1,3,4,28].

This explains why interventions rooted in pharmacotherapy expertise performed better than passive approaches [8,11]. Reconciliation works when discrepancies are interpreted, not merely transcribed [8,40,41]. Education works when it is coupled with local error data and feedback [11,42]. Deprescribing works when it is framed as therapeutic optimization rather than therapeutic retreat [47,48,50,78,79]. Pharmacovigilance works when it recognizes process failures as safety signals rather than noise [6,10,11,61,64].

The centrality of clinical pharmacology to medication safety cannot be overstated. The core problem in complex pharmacotherapy is not administrative complexity alone but therapeutic complexity itself [1,3,4]. Medicines accumulate over time, yet the benefit-harm profile of the total regimen evolves as the patient changes—through aging, frailty, declining renal or hepatic function, cognitive impairment, nutritional status changes, and shifting treatment goals [3,4,53,68]. A medication regimen that was appropriate at initiation may become inappropriate, ineffective, or actively harmful as the patient's clinical status evolves. Medication safety in this context requires clinicians who can think across the entire regimen, integrating pharmacological principles with patient-specific factors, rather than operating within organ-specific silos [1,4,6,70].

This pharmacological framing explains why interventions rooted in pharmacotherapy expertise consistently outperform passive approaches [8,11]. Medication reconciliation achieves its full potential when discrepancies are interpreted clinically—evaluated for indication, dose appropriateness, duplication, interaction risk, and monitoring requirements—rather than merely transcribed from

one list to another [8,40,41]. Educational interventions demonstrate sustained effectiveness only when coupled with local error data, personalized feedback, and practical cognitive aids, rather than relying on one-off didactic sessions [11,42]. Deprescribing succeeds when framed as therapeutic optimization—a positive, patient-centered process of aligning medications with current goals and physiological capacity—rather than as therapeutic retreat or withdrawal of care [47,48,50,64,67]. Pharmacovigilance fulfills its safety mission when it recognizes medication-use process failures as actionable safety signals requiring systemic response, rather than dismissing them as random noise or individual provider errors [6,10,11,72].

6.3. Implications for Practice and Policy

For practice, the implications are immediate. Any patient with complex pharmacotherapy should trigger a structured safety review, particularly at discharge, after acute illness, and after specialist treatment changes [8,26,45,74]. A minimum review set should include current indication, expected benefit, dosing appropriateness, duration, interaction risk, monitoring requirements, adherence barriers, and deprescribing candidates [1,3,4,45].

For policy, medication safety programs should prioritize high-risk transitions and high-risk regimens instead of relying solely on generic education [1,8,26]. Health systems should support multidisciplinary medication stewardship, standardize discharge communication, and ensure that incident reports lead to concrete preventive action [6,8,10]. Where resources are limited, targeted implementation in older adults with polypharmacy may yield the greatest safety return [1,3,4,45,76].

The implications of these findings for clinical practice are immediate and actionable. Any patient with complex pharmacotherapy—particularly those receiving five or more medications, recently discharged from hospital, or with chronic kidney disease, cognitive impairment, or high-risk medication combinations—should trigger a structured medication safety review [1,2,8]. Such a review should encompass current indication, expected benefit, dosing appropriateness (with particular attention to renal and hepatic function), treatment duration, drug-drug and drug-disease interaction risk, monitoring requirements, adherence barriers, and explicit identification of deprescribing candidates [1,3,4,45]. This minimum review set provides a practical, clinically grounded framework that can be implemented across diverse healthcare settings without requiring extensive additional resources.

For health policy, these findings mandate a strategic shift in medication safety programs toward prioritizing high-risk transitions and high-risk regimens, rather than relying solely on generic education or passive safety systems [1,8,26]. Health systems should support multidisciplinary medication stewardship teams that include clinical pharmacists with pharmacotherapy expertise, standardize discharge communication to include explicit medication change documentation, and establish robust incident reporting systems that ensure reported events lead to concrete preventive action [6,8,10,11,78]. Where resources are constrained, targeted implementation in older adults with polypharmacy—the population at highest risk and greatest potential for benefit—may yield the greatest safety return on investment [1,3,4].

6.4. Strengths and Limitations

A major strength of this review is its integration of epidemiologic, interventional, and pharmacovigilance perspectives, which are too often treated separately [2,8,10]. That integrated approach better reflects real-world medication harm. Another strength is its direct clinical framing, which makes the findings more applicable to everyday care [1,3,4].

The review also has limitations. Definitions of polypharmacy and medication-related harm varied across studies [3,23]. Some interventional evidence was heterogeneous in design and intensity [8,11,45]. Pharmacovigilance outcomes were often reported as process measures rather than patient-centered outcomes [10,42]. Publication bias cannot be excluded [11]. Finally, regional data from Georgia and nearby settings remain limited, which underscores the need for locally generated evidence [12,13].

6.5. Future Research

Future work should move beyond counting medicines alone and examine regimen complexity, anticholinergic burden, sedative load, interaction networks, and monitoring failures as distinct safety dimensions [4,53,55]. More studies are needed from Eastern Europe and the South Caucasus [12,13]. Pragmatic trials should test locally feasible models of pharmacist-supported review, discharge reconciliation, and medication safety reporting [8,11,40]. The development of regional medication

safety indicators would also support benchmarking and quality improvement [3,6,23,79].

Future research should move beyond the simple counting of medicines as a proxy for complexity and instead examine regimen complexity as a multidimensional construct incorporating anticholinergic burden, sedative load, interaction networks, monitoring failures, and prescribing cascades as distinct safety dimensions requiring specific intervention strategies [4,53,55,80]. Longitudinal studies are needed to better characterize the natural history of medication-related harm in complex pharmacotherapy and identify critical windows for intervention [2,28]. Pragmatic trials should test locally feasible models of pharmacist-supported medication review, discharge reconciliation, and medication safety reporting, particularly in understudied settings including Eastern Europe and the South Caucasus [1,8,12,77]. The development and validation of regional medication safety indicators—aligned with local prescribing patterns, health system structures, and patient populations—would support meaningful benchmarking and quality improvement [3,6]. Finally, implementation science research is urgently needed to understand the barriers and facilitators to adopting evidence-based medication safety strategies in routine practice, and to design effective strategies for translating evidence into sustained population-level improvements in medication safety [2,6,27].

7. Conclusion

Complex pharmacotherapy is now a routine clinical reality, but the systems designed to keep it safe have not advanced at the same pace. The evidence indicates that medication-related harm is driven by the interaction of regimen burden, inappropriate prescribing, inadequate monitoring, and fragile transitions of care. Pharmacovigilance is not peripheral to this problem; it is one of the tools needed to make harm visible and prevent recurrence. The most effective response is multilevel and practical: medication review, reconciliation, deprescribing, pharmacist-supported education, and active reporting cultures. For Georgia, Armenia and Ukraine and the wider region, embedding these measures into routine care represents a realistic and evidence-based path toward safer medicines use.

Abbreviations

ADE – Adverse Drug Event
ADR – Adverse Drug Reaction
CI – Confidence Interval
ED – Emergency Department
GRADE – Grading of Recommendations Assessment, Development and Evaluation
ICU – Intensive Care Unit
I^2 – I-squared statistic (measure of statistical heterogeneity)
MD – Mean Difference
OR – Odds Ratio
PECOS – Population–Exposure/Intervention–Comparator–Outcome–Setting–Design
PIP – Potentially Inappropriate Prescribing
PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO – International Prospective Register of Systematic Reviews
QALY – Quality-Adjusted Life Year
RCT – Randomized Controlled Trial
ROBINS-I – Risk Of Bias In Non-randomised Studies – of Interventions
RR – Risk Ratio
SMD – Standardized Mean Difference
STOPP – Screening Tool of Older Persons' Prescriptions
WHO – World Health Organization

Acknowledgements

The authors wish to express their sincere gratitude to the faculty members of the Department of Social and Clinical Pharmacy at Tbilisi State Medical University and the Faculty of Medicine, Department of Pharmacy at Akaki Tsereteli State University for their valuable support and constructive feedback during the preparation of this manuscript. We are also deeply grateful to our collaborating institutions —Alte University International School of Medicine (Georgia), Georgian International University (GIU, Georgia), Georgian National University (SEU, Georgia), Yerevan State Medical University after Mkhitar Heratsi (Republic of Armenia), the National University of Pharmacy of Ukraine, Kharkiv State Medical University (Ukraine), the University of the Basque Country (Spain), the University of Georgia (Tbilisi, Georgia), The Caucasus International University (Georgia), Ken Walker International University (Georgia), Republican Hospital (Georgia), and the National Health Center named after Academician O. Gudushauri (Georgia)—for fostering the interdisciplinary collaboration that made this work possible. Special appreciation is extended to our colleagues in the pharmacovigilance and clinical pharmacy communities across Georgia, Armenia, Ukraine, and Spain for their ongoing commitment to advancing medication safety research in the region. We also acknowledge the International Academy of Sciences of Ecology and Life Safety (MANEB), the Academy of the Republic of Armenia for their

support of individual authors' professional development.

Authors' contributions

Nodar Sulashvili: Conceptualization; methodology; formal analysis; writing — original draft; writing — review and editing; supervision; corresponding author.

Margarita Beglaryan: Conceptualization; methodology; writing — review and editing; supervision.

Nato Alavidze: Conceptualization; data collection; methodology; writing — original draft; writing — review and editing; formal analysis; supervision.

Nana Gorgaslidze: Investigation; data curation; validation; writing — review and editing; supervision.

Diego Rada Fernandez de Jauregui: Methodology; validation; writing — review and editing.

Naira Chichoyan: Investigation; supervision; writing — review and editing.

Maka Javakhia: Investigation; methodology; writing — review and editing.

Nino Abuladze: Investigation; data curation; revision of the manuscript; writing — review and editing.

Ada (Adel) Tadevosyan: Investigation; validation; writing — review and editing.

Ketevani Gabunia: Investigation; validation; writing — review and editing.

Vira Kravchenko: Methodology; formal analysis; writing — review and editing.

Olga Shapoval: Investigation; data curation; writing — review and editing.

Igor Seniuk: Investigation; validation; writing — review and editing; supervision.

Maka Buleishvili: Investigation; writing — review and editing.

Natia Kvizhinadze: Investigation; methodology; writing — review and editing.

Marika Sulashvili: Investigation; writing — review and editing.

Marina Giorgobiani: Investigation; writing — review and editing.

Lali Patsia: Investigation; review and editing.

Kakhaber Robakidze: Investigation; formal analysis; methodology; writing — review and editing.

David Aphkhazava: Investigation; validation; writing — review and editing.

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declarations

Ethics approval and consent to participate: Not applicable. This is a systematic review and meta-analysis of previously published, publicly available literature; no original human or animal data were generated, and no individual patient data were collected or analyzed.

Consent for publication: Not applicable. This manuscript contains no individual person's data, images, or other materials requiring consent for publication.

Data availability: All data analyzed in this systematic review and meta-analysis are derived from previously published studies cited in the references section. The search strategy, eligibility criteria, and data extraction methods are fully described in the manuscript to ensure transparency and reproducibility. No additional primary datasets were generated or analyzed during this study.

Competing interests: The authors declare that they have no competing interests, financial or otherwise, that could have influenced the design, conduct, analysis, or reporting of this systematic review and meta-analysis. All authors have completed the ICMJE uniform disclosure form and report no conflicts of interest relevant to this work.

AI use disclosure: Generative artificial intelligence language tools (Claude, Anthropic) were used to assist with manuscript language refinement, structural editing, reference formatting, and GMJ house-style editorial typesetting of this manuscript, including reconstruction of the PRISMA flow diagram (Figure 1) with the counts reported in the Results text. The authors reviewed and verified all clinical content, scientific interpretations, and references; AI was not used to generate study findings, to perform data analysis, to conduct the systematic review or meta-analysis, or to make substantive scientific conclusions. All methodological decisions, data extraction, statistical analyses, risk of bias assessments, GRADE

evaluations, and clinical interpretations were performed independently by the authors. The final manuscript reflects the collective expertise and judgment of all contributing authors, who take full responsibility for the accuracy, integrity, and scientific validity of the work presented.

References

1. World Health Organization. Medication safety in polypharmacy: technical report. Geneva: WHO; 2019.
2. Hodkinson A, Tyler N, Ashcroft DM, Keers RN, Khan K, Phipps D, et al. Preventable medication harm across health care settings: a systematic review and meta-analysis. BMC Med. 2020;18:313. doi:10.1186/s12916-020-01774-9
3. Krustev T, Milushewa P, Tachkov K. Impact of polypharmacy, drug-related problems, and potentially inappropriate medications in geriatric patients and its implications for Bulgaria—narrative review and meta-analysis. Front Public Health. 2022;10:743138. doi:10.3389/fpubh.2022.743138
4. Wimmer BC, Cross AJ, Jokanovic N, Wiese MD, George J, Johnell K, et al. Clinical outcomes associated with medication regimen complexity in older people: a systematic review. J Am Geriatr Soc. 2017;65(4):747-53. doi:10.1111/jgs.14682
5. Sheikh A, Dhingra-Kumar N, Kelley E, Kieny MP, Donaldson LJ. The third WHO global patient safety challenge: tackling medication-related harm. Bull World Health Organ. 2017;95(8):546-6A. doi:10.2471/BLT.17.198002
6. Hamid AAA, Rahim R, Teo SP. Pharmacovigilance and its importance for primary health care professionals. Korean J Fam Med. 2022;43(6):353-61. doi:10.4082/kjfm.21.0193
7. World Health Organization. Reporting and learning systems for medication errors: the role of pharmacovigilance centres. Geneva: WHO; 2014.
8. Mekonnen AB, McLachlan AJ, Brien JE. Effectiveness of pharmacist-led medication reconciliation programmes on clinical outcomes at hospital transitions: a systematic review and meta-analysis. BMJ Open. 2016;6:e010003. doi:10.1136/bmjopen-2015-010003
9. Mekonnen AB, Redley B, de Courten B, Manias E. Potentially inappropriate prescribing and its associations with health-related and system-related outcomes in hospitalised older adults: a systematic review and meta-analysis. Br J Clin Pharmacol. 2021;87(11):4150-72. doi:10.1111/bcp.14870
10. Paudyal V, Al-Hamid A, Bowen M, Hadi MA, Hasan SS, Jalal Z, et al. Interventions to improve spontaneous adverse drug reaction reporting by healthcare professionals and patients: systematic review and meta-analysis. Expert Opin Drug Saf. 2020;19(9):1173-91. doi:10.1080/14740338.2020.1807003
11. Jaam M, Naseralallah LM, Hussain TA, Pawluk SA. Pharmacist-led educational interventions provided to healthcare providers to reduce medication errors: a systematic review and meta-analysis. PLoS One. 2021;16(6):e0253588. doi:10.1371/journal.pone.0253588
12. Sulashvili N, Beglaryan M, Alavidze N, et al. Medication safety challenges in Georgia: a scoping review of current evidence and policy gaps. Georgian Med J. 2024;12(3):101-10.
13. Pkhakadze G, Sulashvili N, Gorgaslidze N. Health system readiness for pharmacovigilance in the South Caucasus region. Georgian Med J. 2023;11(2):45-52.
14. Naseralallah L, Koraysh S, Alasmar M, Aboujabal B. The role of pharmacists in mitigating medication errors in the perioperative setting: a systematic review. Syst Rev. 2025;14(1):12. doi:10.1186/s13643-024-02710-1
15. Potentially inappropriate prescribing among older adults receiving home health care service: a retrospective study in Saudi Arabia. Home Health Care Manag Pract. 2025. doi:10.1177/10848223241308483
16. Prevalence of potentially inappropriate prescribing, potentially inappropriate medications, potential prescribing omissions, and potential drug–drug interactions among older adults in Ethiopia: a systematic review and meta-analysis. BMJ Open. 2025;16(3):e103495.
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi:10.1136/bmj.n71
18. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa: Ottawa Hospital Research Institute; 2011.
19. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928. doi:10.1136/bmj.d5928
20. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919. doi:10.1136/bmj.i4919
21. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7(3):177-88. doi:10.1016/0197-2456(86)90046-2
22. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008;336(7650):924-6. doi:10.1136/bmj.39489.470347.AD
23. Delara M, Murray L, Jafari B, et al. Prevalence and factors associated with polypharmacy: a systematic review and meta-analysis. BMC Geriatr. 2022;22(1):601. doi:10.1186/s12877-022-03279-x
24. O'Mahony D, O'Sullivan D, Byrne S, O'Connor MN, Ryan C, Gallagher P. STOPP and START criteria for potentially inappropriate prescribing in older people: version 2. Age Ageing. 2015;44(2):213-8. doi:10.1093/ageing/afu145
25. Liew TM, Lee CS, Goh Shawn KL, Chang ZY. Potentially inappropriate prescribing among older

persons: a meta-analysis of observational studies. Ann Fam Med. 2019;17(3):257-66. doi:10.1370/afm.2373
26. Leendertse AJ, Egberts ACG, Stoker LJ, van den Bemt PMLA. Frequency of and risk factors for preventable medication-related hospital admissions in the Netherlands. Arch Intern Med. 2008;168(17):1890-6. doi:10.1001/archinternmed.2008.3
27. Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients: excess length of stay, extra costs, and attributable mortality. JAMA. 1997;277(4):301-6.
28. Prevalence of and risk factors for drug-related readmissions in older adults: a systematic review and meta-analysis. Drugs Aging. 2024;41(1):1-11. doi:10.1007/s40266-023-01076-8
29. Ng Y, Hsu JTY, Ng NNE, et al. Evaluating the role of clinical decision support systems in medication safety for older people: a systematic review. Age Ageing. 2025;54(7):afaf206. doi:10.1093/ageing/afaf206
30. Russmann S, Martinelli F, Jakobs F, et al. Identification of medication prescription errors and factors of clinical relevance in 314 hospitalized patients for improved multidimensional clinical decision support algorithms. J Clin Med. 2023;12(15):4920. doi:10.3390/jcm12154920
31. Tian F, Chen Z, Zeng Y, et al. Prevalence of use of potentially inappropriate medications among older adults worldwide: a systematic review and meta-analysis. JAMA Netw Open. 2023;6(8):e2326910.
32. Szoszkiewicz M, Deskur-Śmielecka E, Styszyński A, et al. Potentially inappropriate prescribing identified using STOPP/START version 3 in geriatric patients and comparison with version 2: a cross-sectional study. J Clin Med. 2024;13(20):6043. doi:10.3390/jcm13206043
33. Thomas RE, Azzopardi R, Asad M, Tran D. Multi-year retrospective analysis of mortality and readmissions correlated with STOPP/START and the American Geriatric Society Beers Criteria applied to Calgary hospital admissions. Geriatrics. 2023;8(5):100. doi:10.3390/geriatrics8050100
34. Brannigan R, Hughes JE, Moriarty F, et al. Potentially inappropriate prescribing and potential prescribing omissions and their association with adverse drug reaction-related hospital admissions. J Clin Med. 2024;13(2):323. doi:10.3390/jcm13020323
35. Bhagavathula AS, Gebreyohannes EA, Fialova D. Prevalence of polypharmacy and risks of potentially inappropriate medication use in the older population in a developing country: a systematic review and meta-analysis. Gerontology. 2022;68(2):136-145. doi:10.1159/000516075
36. McDonald EG, Wu PE, Rashidi B, et al. The MedSafer Study—Electronic decision support for deprescribing in hospitalized older adults: A cluster randomized clinical trial. JAMA Intern Med. 2022;182(3):265-273. doi:10.1001/jamainternmed.2021.7429
37. Jovevski JJ, Smith CR, Roberts JL, et al. Implementation of a compulsory clinical pharmacist-led medication deprescribing intervention in high-risk seniors in the emergency department. Acad Emerg Med. 2023;30(4):410-419. doi:10.1111/acem.14699
38. Trends in drug duplications in Swedish older adults: a nationwide register study from 2006 to 2021. Drugs Aging. 2024;41(9):775-781. doi:10.1007/s40266-024-01145-6
39. Pharmaceutical care for the patients admitted to a multidisciplinary complex chronic patient unit. Farmacia Hosp. 2023;47(3):106-112. doi:10.1016/S1130-6343(23)00004-1
40. Shafaamri M. Effects of pharmacist-led medication reconciliation services on geriatric patients at a leading military hospital in Jordan. ClinicalTrials.gov. NCT06610292. Updated September 19, 2024.
41. Proactive versus retroactive medication reconciliation in acute coronary syndrome patients: a randomized trial. Explor Res Clin Soc Pharm. 2025;18:100547. doi:10.1016/j.rcsop.2025.100547
42. Carollo M, Crisafulli S, Vitturi G, Besco M, Hinek, Franchi C, et al. Clinical impact of medication review and deprescribing in older inpatients: a systematic review and meta-analysis. J Am Geriatr Soc. 2024;72:3219-3238. doi:10.1111/jgs.19035
43. Bloomfield HE, Greer N, Linsky AM, Bolduc J, Naidl T, Vardeny O, et al. Deprescribing for community-dwelling older adults: a systematic review and meta-analysis. J Gen Intern Med. 2020;35(11):3323-32. doi:10.1007/s11606-020-06089-2
44. Rankin A, Cadogan CA, Patterson SM, Kerse N, Cardwell CR, Bradley MC, et al. Interventions to improve the appropriate use of polypharmacy for older people. Cochrane Database Syst Rev. 2018;9:CD008165. doi:10.1002/14651858.CD008165.pub4
45. Zhou D, Chen Z, Tian F. Deprescribing interventions for older patients: a systematic review and meta-analysis. J Am Med Dir Assoc. 2023;24(11):1718-1725. doi:10.1016/j.jamda.2023.07.016
46. Pharmacist-led deprescribing to improve medication safety in older patients with hip fractures. BMC Geriatr. 2025;25:494. doi:10.1186/s12877-025-06250-8
47. Acheampong F, Anto BP, Koffuor GA. Medication safety strategies in hospitals--a systematic review. Int J Risk Saf Med. 2014;26(3):117-31. PMID: 25214157. doi:10.3233/JRS-140623
48. Medication errors: prevention using information technology systems. Agrawal A. Br J Clin Pharmacol. 2009 Jun;67(6):681-6. doi:10.1111/j.1365-2125.2009.03427.x
49. Alavidze N, Javakhia M, Abuladze N, Gabunia K, Sulashvili N, Chubinidze N. Pharmacist-Led Interventions in the Management of Polypharmacy: A Systematic Review of Clinical Effectiveness, Prescribing Quality and Patient Safety Outcomes. GMJ . 2026 May 9 [cited 2026 Sep. 6];1(2):1-16. Available from: https://gmj.ge/index.php/pub/article/view/41
50. Peters T, Soanes N, Abbas M, Ahmad J, Delumeau JC, Herrero-Martinez E, Paramananda M, Piper J, Smail-Aoudia F, van der Spuij W, Veizovic T, Winstanley G; EFPIA International Pharmacovigilance Group. Effective

Pharmacovigilance System Development: EFPIA-IPVG Consensus Recommendations. Drug Saf. 2021 Jan;44(1):17-28. Epub 2020 Dec 8. doi:10.1007/s40264-020-01008-0
51. Tsintis P, La Mache E. CIOMS and ICH initiatives in pharmacovigilance and risk management: overview and implications. Drug Saf. 2004;27(8):509-17. doi:10.2165/00002018-200427080-00004
52. Bahri P, Genov G, Arlett P, Šarinić VM, Korakianiti E, Nolte A, Huber M, Straus SMJM. The STAR Compass to Guide Future Pharmacovigilance Based on a 10-Year Review of the Strengthened EU System. Drug Saf. 2024 Oct;47(10):941-956. Epub 2024 Jul 10. doi:10.1007/s40264-024-01451-3
53. Adopo D, Daynes P, Benkebil M, Debs A, Jonville-Berra AP, Polard E, Micallef J, Maison P. Patient involvement in pharmacovigilance: determinants and evolution of reporting from 2011 to 2020 in France. Eur J Clin Pharmacol. 2023;79:229–36. doi:10.1007/s00228-022-03422-y
54. Varallo FR, Guimaraes SOP, Abjaude SAR, Mastroianni PC. Causes for the underreporting of adverse drug events by health professionals: a systematic review. Rev Esc Enferm USP. 2014;48:739–47. doi:10.1590/S0080-623420140000400023
55. Al Dweik R, Stacey D, Kohen D, Yaya S. Factors affecting patient reporting of adverse drug reactions: a systematic review. Br J Clin Pharmacol. 2017;83:875–83. doi:10.1111/bcp.13159
56. Januskiene J, Segec A, Slattery J, Genov G, Plueschke K, Arlett P, Kurz X. What are the patients' and health care professionals' understanding and behaviors towards adverse drug reaction reporting and additional monitoring? Pharmacoepidemiol Drug Saf. 2021;30:334–41. doi:10.1002/pds.5162
57. Amiri A, Okai J, Bahri P, Macolić ŠV. The fundamental value of exposure data for pharmacovigilance: review of different aggregation levels of exposure data in pharmaceutical companies' period Safety update reports [abstract of poster at 20th Annual Meeting of the International Society of Pharmacovigilance (ISoP) in November 2021]. Drug Saf. 2021;44(1402):P002.
58. Grupstra RJ, Goedecke T, Scheffers J, Strassmann V, Gardarsdottir H. Review of studies evaluating effectiveness of risk minimisation measures assessed by the European Medicines Agency between 2016 and 2021. Clin Pharmacol Ther. 2023;114:1285–92. doi:10.1002/cpt.3034
59. World Health Organization (WHO). Guidance for clinical case management of thrombosis with thrombocytopenia syndrome (TTS) following vaccination to prevent coronavirus disease (COVID-19) [interim guidance]. Geneva: WHO; 2021.
60. Candore G, Monzon S, Slattery J, Piccolo L, Postigo R, Xurz X, Strauss S, Arlett P. The impact of mandatory reporting of non-serious safety reports to EudraVigilance on the detection of adverse reactions. Drug Saf. 2022;45:83–95. doi:10.1007/s40264-021-01137-0
61. European Medicines Agency (EMA). Measuring the impact of pharmacovigilance activities. Amsterdam: EMA. https://www.ema.europa.eu/en/human-regulatory/overview/pharmacovigilance-overview#measuring-the-impact-of-pharmacovigilance-activities-(updated)-section. Accessed 28 Feb 2023.
62. Goedecke T, Morales D, Pacurariu A, Kurz X. Measuring the impact of medicines regulatory interventions: systematic review and methodological considerations. Br J Clin Pharmacol. 2018;84:419–33. doi:10.1111/bcp.13469
63. European Medicines Agency (EMA). Public hearing on valproate: first experience and lessons learnt. London: EMA; 2017.
64. Bahri P, Morales DR, Inoubli A, Dogné JM, Straus SMJM. Proposals for engaging patients and healthcare professionals in risk minimisation from an analysis of stakeholder input to the EU valproate assessment using the novel analysing stakeholder safety engagement tool (ASSET). Drug Saf. 2021;44:193–209. doi:10.1007/s40264-020-01005-3
65. Bahri P, Pariente A. Systematising pharmacovigilance engagement of patients, healthcare professionals and regulators: a practical decision guide derived from the International Risk Governance Framework for engagement events and discourse. Drug Saf. 2021;44:1193–208. doi:10.1007/s40264-021-01111-w
66. Brown P, Bahri P. 'Engagement' of patients and healthcare professionals in regulatory pharmacovigilance: establishing a conceptual and methodological framework. Eur J Clin Pharmacol. 2019;75:1181–92. doi:10.1007/s00228-019-02705-1
67. Bahri P. A multilayered research framework for humanities and epidemiology of medicinal product risk communication. In: Bahri P, editor. Communicating about risks and safe use of medicines: real life and applied research, Chapter 1. Singapore: Springer Nature; 2020.
68. European Medicines Agency (EMA). EudraVigilance: European database of suspected adverse drug reaction reports. https://www.adrreports.eu. Accessed 25 Oct 2022.
69. Bhasale AL, Sarpatwari A, et al. Postmarket safety communication for protection of public health: a comparison of regulatory policy in Australia, Canada, the European Union, and the United States. Clin Pharmacol Ther. 2021;109:1424–42. doi:10.1002/cpt.2010
70. Lofstedt R, Bouder F, Chakraborty S. Transparency and the Food and Drug Administration: quantitative study. J Health Commun. 2013;18:391–6. doi:10.1080/10810730.2012.696229
71. Khan MAA, Nwokike J, Rauf A, Babar ZU. A comparative analysis of three pharmacovigilance system assessment tools. PLoS One. 2025 Jul 8;20(7):e0327363. doi:10.1371/journal.pone.0327363
72. Sulashvili N, Beglaryan M, Gorgaslidze N, Gabunia L, Alavidze N, Abuladze N, et al. The manifestation of key issue aspects of pharmacists' occupational features and study of some driving forces impact on pharmacists' profession and role expansion. PIRETC J Soc Res Behav Sci. 2024;32(03):35-52.
73. Sulashvili N, Beglaryan M, Gorgaslidze N, Kocharyan S, Chichoyan N, Gabunia L, et al. The disclosure of features, characteristics, possibilities and specialties of clinical pharmacists as mediator among doctors

and patients for enhancement public health sector in a global world. Exp Clin Med. 2023;(4):57-61.
74. The importance of pharmacovigilance. World Health Organisation, 2015
75. Sulashvili N, Gabunia L, Gorgaslidze N, Beglaryan M, Alavidze N, Abuladze N, et al. The key issues relating to features, summons, proclivities, prosperities, striving, exploring, innovations of clinical pharmacists' profession and pharmaceutical organizational enhancement and regulation extension issues in modern medicine. In: Materials of the III International Scientific and Practical Conference, "Microbiological and Immunological Research in Modern Medicine". Kharkiv: National University of Pharmacy of Ukraine; 2023. p. 24-26.
76. Garashi HY, Steinke DT, Schafheutle EI. A Systematic Review of Pharmacovigilance Systems in Developing Countries Using the WHO Pharmacovigilance Indicators. Ther Innov Regul Sci. 2022 Sep;56(5):717-743. Epub 2022 Jun 3. doi:10.1007/s43441-022-00415-y
77. Lapeyre-Mestre M, Micallef J, Hacquet R, Jouanjus E. Pharmacovigilance in the field of addiction: challenges and emerging solutions. Expert Rev Clin Pharmacol. 2025 Dec;18(12):989-1003. Epub 2025 Dec 9. doi:10.1080/17512433.2025.2600414
78. Khan Z, Moriarty F. Strengthening Pharmacovigilance Reporting for Withdrawal Reactions to Support Deprescribing. Clin Pharmacol Ther. 2026 Sep;120(3):663-666. Epub 2026 Jun 6. doi:10.1002/cpt.70356
79. Norén GN, Donegan K, Muñoz MA, Alshammari TM, Pratt N, Candore G, Morales D, Rijnbeek P, Bate A, Postigo R, Toh S, Trifirò G, Gabarro MS, Cave A, Ryan PB. Recommendations to Enable Broader Use of Real-World Evidence to Inform Decision-Making Throughout Pharmacovigilance Signal Management. Pharmacoepidemiol Drug Saf. 2025 Oct;34(10):e70231. doi:10.1002/pds.70231
80. Gauffin O, Brand JS, Vidlin SH, Sartori D, Asikainen S, et al. Supporting Pharmacovigilance Signal Validation and Prioritization with Analyses of Routinely Collected Health Data: Lessons Learned from an EHDEN Network Study. Drug Saf. 2023 Dec;46(12):1335-1352. doi:10.1007/s40264-023-01353-w

Author details

Nodar Sulashvili (NS), Professor, Alte University International School of Medicine; Georgian International University (GIU); Georgian National University (SEU); Tbilisi, Georgia.

Margarita Beglaryan (MB), Yerevan State Medical University after Mkhitar Heratsi, Yerevan, Republic of Armenia.

Nato Alavidze (NA), Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

Nana Gorgaslidze (NG), Tbilisi State Medical University, Department of Social and Clinical Pharmacy, Tbilisi, Georgia.

Diego Rada Fernandez de Jauregui (DRFJ), Pharmacy Faculty, University of the Basque Country, Spain.

Naira Chichoyan (NC), Yerevan State Medical University after Mkhitar Heratsi, Department of Pharmacognosy, Yerevan, Republic of Armenia.

Maka Javakhia (MJ), Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

Nino Abuladze (NAb), Akaki Tsereteli State University, Faculty of Medicine, Kutaisi, Georgia.

Ada (Adel) Tadevosyan (AT), Yerevan State Medical University after Mkhitar Heratsi; International Academy of Sciences of Ecology and Life Safety (MANEB); Tbilisi, Georgia – Yerevan, Armenia – Los Angeles, USA.

Ketevani Gabunia (KG), Akaki Tsereteli State University, Faculty of Medicine, Department of Pharmacy, Kutaisi, Georgia.

Vira Kravchenko (VK), National University of Pharmacy of Ukraine, Biological Chemistry Department, Kharkiv, Ukraine.

Olga Shapoval (OS), Kharkiv State Medical University, Department of Pharmacology and Medical Prescription, Kharkiv, Ukraine.

Igor Seniuk (IS), National University of Pharmacy of Ukraine, Biological Chemistry Department, Kharkiv, Ukraine.

Maka Buleishvili (MBu), Georgian International University (GIU), Faculty of Medicine, Tbilisi, Georgia.

Natia Kvizhinadze (NK), Tbilisi State Medical University, Department of Social and Clinical Pharmacy, Tbilisi, Georgia.

Marika Sulashvili (MS), Tbilisi State Medical University, Department of Molecular and Medical Genetics; The University of Georgia; Tbilisi, Georgia.

Marina Giorgobiani (MG), Tbilisi State Medical University, Faculty of Public Health, Department of Hygiene and Medical Ecology, Tbilisi, Georgia.

Lali Patsia (LP), Tbilisi State Medical University; Ken Walker International University; International School of Medicine, Alte University; Republican Hospital; Tbilisi, Georgia.

Kakhaber Robakidze (KR), The Caucasus International University; International School of Medicine, Alte University; National Health Center named after Academician O. Gudushauri; Tbilisi, Georgia.

David Aphkhazava (DA), The University of Georgia, Tbilisi, Georgia.

ORCID iDs.

Nodar Sulashvili: 0000-0002-9005-8577

Margarita Beglaryan: 0000-0003-3697-6390
Nato Alavidze: 0000-0001-6695-5924
Nana Gorgaslidze: 0000-0002-4563-5224
Diego Rada Fernandez de Jauregui: 0000-0002-9109-1088
Naira Chichoyan: 0000-0003-3905-3372
Maka Javakhia: 0000-0002-9869-9125
Nino Abuladze: 0000-0003-2189-7470
Ada (Adel) Tadevosyan: Not applicable
Ketevani Gabunia: 0000-0002-5857-6593
Vira Kravchenko: 0000-0001-6335-2490
Olga Shapoval: 0000-0002-1971-2863
Igor Seniuk: 0000-0003-3819-7331
Maka Buleishvili: 0009-0004-2657-8473
Natia Kvizhinadze: Not applicable
Marika Sulashvili: 0000-0002-6338-4262
Marina Giorgobiani: 0000-0003-0686-5227
Lali Patsia: 0009-0007-7125-6862
Kakhaber Robakidze: Not provided
David Aphkhazava: 0000-0001-6216-6477

Cite this article as: Sulashvili N, Beglaryan M, Alavidze N, Gorgaslidze N, Rada Fernandez de Jauregui D, Chichoyan N, Javakhia M, Abuladze N, Tadevosyan A, Gabunia K, Kravchenko V, Shapoval O, Seniuk I, Buleishvili M, Kvizhinadze N, Sulashvili M, Giorgobiani M, Patsia L, Robakidze K, Aphkhazava D. Multidisciplinary clinical pharmacology in complex pharmacotherapy: drug-related errors, pharmacovigilance, and evidence-based strategies for medication safety—a systematic review and meta-analysis. Georgian Med J. 2026;1(4):a207.
https://doi.org/10.66636/gmj.v1.i4.a207