

From Pharmacogenomic Testing to Prescribing Action: A Scoping Review of Clinical Integration, Decision Support, Pharmacist Roles, and Implementation Across Pharmacy Practice Settings, 2017–2026

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ABSTRACT

Pharmacogenomic testing can identify clinically relevant gene–drug variation, but its value in pharmacy practice depends on whether results are converted into interpretable and timely prescribing decisions. Implementation therefore extends beyond laboratory testing to result delivery, decision support, professional interpretation, workflow integration, and continuity across care settings. To map how pharmacogenomic testing was integrated into prescribing workflows across pharmacy practice settings from 2017 to 2026, with particular attention to clinical integration pathways, decision-support modalities, pharmacist roles, implementation conditions, and evidence gaps. A scoping-review approach was used to map heterogeneous implementation evidence. Eligible literature addressed clinically actionable pharmacogenomics, clinical integration, decision support, pharmacist participation, prescribing response, or implementation within identifiable healthcare settings. Evidence was charted by setting, testing model, gene–drug scope, workflow location, interpretation actor, pharmacist function, prescribing-action endpoint, implementation conditions, and evidential boundaries. The mapped literature encompassed academic health systems, primary care, community pharmacy, rural systems, specialty services, inpatient care, behavioral health, and multinational implementation programs. Testing availability did not consistently correspond to prescribing action. Decision support varied in timing, specificity, workflow position, and clinical contextualization, while pharmacists occupied roles extending from test initiation to interpretation and prescriber consultation. Implementation barriers and enabling conditions were setting-dependent. Pharmacogenomic implementation is better understood as a series of distinguishable clinical states rather than as test availability alone. The review maps where translation toward prescribing action occurs, where it fails, and where evidence remains limited without assuming that implementation necessarily produces clinical benefit.

Impact Statements

- Pharmacogenomic testing should not be treated as synonymous with clinical implementation; result interpretation, workflow delivery, professional action, and prescribing response are analytically distinct.
- Pharmacists may contribute at several points between test selection and medication modification, but their roles vary substantially across practice settings.
- Decision-support design and implementation conditions should be evaluated in context because technical availability alone does not establish prescribing impact or sustainability.

Keywords: Pharmacogenomics, Clinical pharmacy, Clinical decision support, Pharmacists, Implementation science, Prescribing

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Introduction

Pharmacogenomics has progressed from identifying genetic associations toward providing clinically interpretable information for selected gene–drug pairs. However, the existence of an actionable genotype–phenotype relationship does not itself establish that testing will alter treatment. Clinical translation requires that a result be available at an appropriate decision point, linked to sufficiently specific prescribing guidance, interpreted within the patient's therapeutic context, and acted upon by a responsible clinician or care team [1]. The implementation problem is therefore situated between molecular information and medication management rather than at the laboratory boundary alone.

The remaining implementation challenge spans health-system barriers, primary-care constraints, and the practical integration of pharmacogenomic information into clinical and longitudinal medication workflows [2–4]. These dimensions operate at different levels. A gene–drug recommendation may be clinically interpretable yet unavailable within the prescribing interface; a result may be visible but presented too late to influence therapy; or a pharmacist may identify an actionable finding without having a reliable route for communicating or implementing a recommendation. Conversely, a technically sophisticated program may achieve high result availability without demonstrating that prescribing decisions change. This distinction is particularly important for a pharmacy-practice review because pharmacists may participate in testing, interpretation, communication, medication selection, dosing, follow-up, and implementation design.

Accordingly, this review treats pharmacogenomic implementation as a set of observable but non-equivalent states: testing, actionable interpretation, result delivery, decision support, professional recommendation, and enacted prescribing action. These states provide the organizing logic for mapping how evidence has developed across pharmacy practice settings between 2017 and 2026.

Aim

Existing evidence syntheses have examined pharmacogenomic clinical decision support and community-pharmacy implementation as partly separate domains [5, 6]. Such work is essential, but it leaves a broader practice question: how do different clinical environments connect testing with medication decisions, and where do pharmacists enter that process? A cross-setting view is required because the same pharmacogenomic result may be handled differently in an academic medical center, community pharmacy, specialty clinic, primary-care service, or rural health system.

The aim of this scoping review was therefore to map the clinical and organizational routes by which pharmacogenomic information moves toward prescribing action. Particular attention was given to structured result availability and electronic decision support because EHR architecture can determine whether genomic information is available when prescribing occurs [7]. Community-pharmacy implementation was considered separately rather than subsumed within health-system models because professional roles, infrastructure, reimbursement, access to clinical information, and interprofessional communication can differ substantially in that environment [8].

The review did not seek to estimate a pooled effect of pharmacogenomic testing or to rank implementation models by effectiveness. Instead, it mapped where evidence exists across testing models, prescribing contexts, decision-support approaches, pharmacist functions, implementation stages, and practice settings. A secondary objective was to identify where apparent implementation success reflects feasibility, adoption, recommendation generation, or workflow integration rather than a demonstrated change in prescribing or patient outcomes.

Materials and Methods

A scoping-review design was selected because the literature combines clinical guidelines, implementation studies, decision-support evaluations, pharmacist-led service descriptions, surveys, and evidence syntheses that address different stages of the testing-to-prescribing process. Reporting was structured according to PRISMA-ScR principles [9], while conduct and evidence mapping followed contemporary methodological guidance for scoping reviews [10]. The design was intended to characterize the range and organization of the evidence rather than convert heterogeneous study designs into a pooled estimate of clinical effectiveness.

The distinction between scoping and systematic effectiveness review was maintained throughout. Scoping reviews are particularly appropriate when the purpose is to clarify concepts, characterize evidence types, map practice contexts, and identify gaps across a heterogeneous field [11]. Accordingly, the analytic unit was not restricted to

a single clinical outcome. Studies could contribute evidence concerning testing initiation, result integration, decision-support design, pharmacist participation, recommendation generation, prescribing response, implementation barriers, or sustainability.

Eligibility and charting domains were defined before synthesis so that later interpretation would not depend on retrospectively selecting only favorable implementation outcomes. This approach is consistent with guidance emphasizing explicit protocol-level decisions for scoping-review questions, eligibility, and data handling [12]. No meta-analysis was planned because the included designs, clinical settings, interventions, and outcomes were not assumed to represent a common estimand.

Review questions and eligibility criteria

The review asked how pharmacogenomic testing was connected to medication decision-making across pharmacy practice settings; which decision-support approaches were used; what roles pharmacists performed; which organizational and contextual conditions enabled or constrained implementation; and where evidence remained sparse. Eligibility therefore required more than genetic association alone. For the purposes of this review, a pharmacogenomic result was considered clinically actionable only when the literature linked genotype or inferred phenotype to an evidence-based prescribing interpretation, such as drug selection, dose modification, enhanced monitoring, or avoidance [13–15].

Eligible articles were peer-reviewed publications from 2017 through 2026 addressing pharmacogenomic implementation, prescribing guidance, decision support, pharmacy practice, or clinically relevant workflow integration. Both reactive and pre-emptive testing were eligible, as were single-gene and multigene approaches. Prospective implementation studies were included where they informed how a testing strategy entered real clinical care; multicountry panel-based implementation provided one important example of this evidence class [16].

Studies were excluded when they addressed genetic association without a prescribing or implementation connection, lacked sufficient clinical or practice context, or were materially incompatible with the review's testing-to-action focus. Heterogeneous designs were retained for mapping but were not treated as methodologically interchangeable. Patient outcomes, feasibility measures, clinician behavior, pharmacist activity, alert metrics, and implementation outcomes were coded as distinct evidence types.

Information sources and search strategy

The evidence search used PubMed-indexed retrieval supplemented by publisher and journal-site searches, DOI and title verification, and backward and forward reference chaining. The review period extended from 1 January 2017 through 19 August 2026. Search concepts were developed around pharmacogenomics and pharmacogenetics in combination with implementation, clinical integration, prescribing, medication management, clinical decision support, electronic health records, pharmacists, community pharmacy, primary care, health systems, workflow, barriers, facilitators, and related terms.

Search construction was not restricted to explicit prescribing-outcome terminology. Methodological evidence indicates that depending too heavily on outcome terms can reduce retrieval sensitivity when outcomes are inconsistently described or indexed [17, 18]. This was particularly relevant because implementation papers may describe pharmacist consultation, alert response, recommendation acceptance, workflow integration, or service adoption without using a common prescribing-action label.

Information sources, search dates, search concepts, and supplementary searching were documented in accordance with PRISMA-S reporting principles [19]. Complete exports were unavailable for some supplementary searches; early retrieval and deduplication counts therefore could not be reported.

Study selection

Screening was undertaken against the predefined publication period, peer-review status, DOI verification, journal eligibility, and direct relevance to the review domains. Practice-oriented evidence was intentionally broad enough to include different operational models. Pharmacy-led health-system programs were eligible because they demonstrated how testing, service design, reimbursement, laboratory processes, and medication management could be connected within an implementation structure [20]. Pre-emptive pharmacogenomic programs embedded within academic EHR infrastructure represented a second eligible model [21]. Pharmacist-led specialty services were also retained where they demonstrated direct integration of pharmacogenomic interpretation into clinical care-team workflows [22].

Fifty-two unique articles underwent eligibility assessment. Eighteen did not meet the review criteria, and 34 sources were included in the mapped evidence set. Earlier database and supplementary-search totals could not be established from the available search records.

Figure 1 presents the available selection counts and identifies the stages for which totals were unavailable.

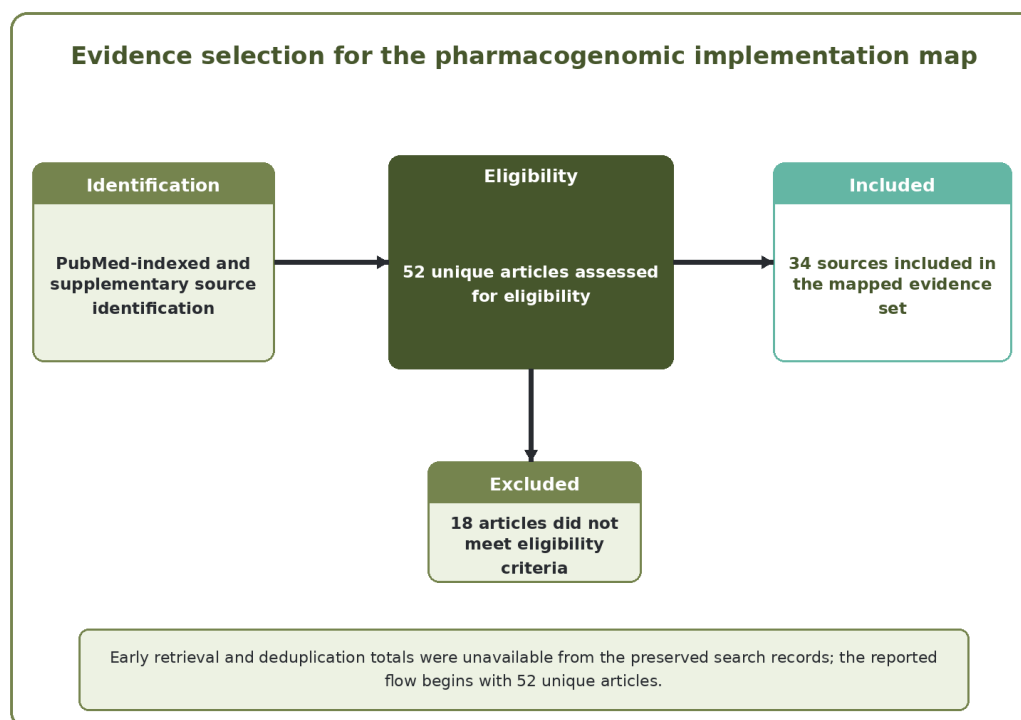


Figure 1. Selection of evidence for the pharmacogenomic testing-to-prescribing-action review

Data charting and coding

Data charting was organized around variables needed to distinguish testing availability from prescribing action. Methodological guidance for scoping reviews supports extraction structures that are aligned with the review questions while remaining sufficiently iterative to accommodate evidence heterogeneity [23]. Accordingly, each source was charted by country or region, practice setting, population or unit of analysis, gene–drug or panel scope, testing model, level of analysis, result-delivery mechanism, decision-support modality, pharmacist role, prescriber interaction, implementation stage, prescribing-action endpoint, barriers or enabling conditions, and reported limitations.

Decision support was not coded as a binary present/absent variable. Its timing, specificity, workflow position, and clinical contextualization were treated separately because an alert may be technically active while remaining poorly matched to the medication decision. Evidence showing that dose criteria can materially alter the relevance and burden of pharmacogenomic alerts illustrates why the logic governing activation must be distinguished from the mere existence of an alert [24].

Therapy-specific workflow dependencies were also retained rather than collapsed into a generic implementation category. Genotype-guided tacrolimus dosing, for example, requires coordination among testing timing, interpretation, dose selection, therapeutic monitoring, and transplant workflow [25]. Similar distinctions were applied across other settings where the pathway from result availability to prescribing action depended on when information became available, who interpreted it, and what authority or mechanism existed to alter therapy.

The coding framework therefore preserved six analytically distinct states: testing performed, actionable result available, result delivered, decision support encountered, medication recommendation generated, and prescribing action enacted. This six-state distinction is a proposed synthesis used to organize heterogeneous implementation evidence; it is not presented as a compulsory sequence or as a validated implementation model.

Results and Discussion

The mapped evidence did not support treating pharmacogenomic implementation as a single exposure or outcome. In the prospective ACCOuNT implementation trial, pharmacogenomic clinical decision support was frequently used, yet its use did not significantly reduce genomically discordant prescribing, demonstrating that information access and prescribing concordance are separable implementation states [26]. This null finding was retained as an important boundary on interpretations that equate decision-support use with demonstrated clinical effect.

The practice environments represented in the evidence were heterogeneous. A large rural health system implemented CYP2C19- and CYP2D6-guided antidepressant care, showing that pharmacogenomic implementation is not confined to large urban academic centers [27]. However, evidence from one rural system cannot establish transferability to rural organizations with different laboratory access, informatics capacity, staffing, or referral structures.

Workforce evidence also showed a gap between favorable orientation toward pharmacogenomics and practical implementation capability. In a survey of pharmacists in Türkiye, limited training and real-world experience with pharmacogenomic recommendations coexisted with generally positive attitudes toward testing [28]. Across the mapped literature, feasibility, adoption, alert response, recommendation generation, prescribing change, and patient outcome were therefore treated as different result domains rather than successive indicators of the same implementation success.

Across these studies, the location of the bottleneck varied. Some programs primarily addressed access to testing or storage of results, whereas others focused on interpretation, clinician notification, recommendation uptake, or maintenance of genomic information for future prescribing. The mapped pattern therefore argues against using a single implementation-status label when the underlying services have reached materially different clinical stages.

Characteristics of the mapped evidence

The evidence base covered multiple entry points into medication management. Pharmacists were not restricted to receiving completed genetic reports: a primary-care pilot demonstrated pharmacist-initiated pre-emptive testing, placing pharmacy practice upstream of interpretation and prescribing [29]. Other sources positioned pharmacists within interpretation, recommendation, education, service design, and communication with prescribers.

Community-pharmacy evidence formed a distinct implementation stream. A recent scoping review found heterogeneous models encompassing feasibility, adoption, acceptability, pharmacist activities, and implementation barriers rather than a uniform pathway to medication change [30]. This heterogeneity matters because access to the medical record, authority to order testing, reimbursement mechanisms, and communication routes can differ from those available to pharmacists embedded in health systems.

The mapped settings also included integrated behavioral health for an underserved population, where pharmacogenomics was incorporated through a multidisciplinary service rather than an isolated laboratory-to-prescriber transaction [31]. Taken together, the evidence suggests a distributed field in which similar genetic information enters care through different professional, technological, and organizational arrangements. **Table 1** charts representative implementation instances by the dimensions most relevant to movement toward prescribing action.

Table 1. Where pharmacogenomic testing enters pharmacy practice and how implementation proceeds

Implementation instance	Setting and population	Gene/drug scope	Testing model	Pharmacist role	Prescribing-action endpoint	Implementation stage
Primary-care pre-emptive pilot	Primary-care patients	Actionable panel	Pre-emptive	Initiates testing; interprets results	Recommendation to prescriber	Pilot integration
Community-pharmacy programs	Community-pharmacy users	Variable single-gene/panel scope	Reactive or pre-emptive	Testing, counseling, referral, recommendation	Variable; often feasibility or recommendation	Heterogeneous adoption
Rural antidepressant program	Large rural health system	CYP2C19/CYP2D6-antidepressants	Clinically integrated genotyping	Supports interpretation/workflow	Antidepressant prescribing decision	System implementation

Inpatient AC COuNT program	African American inpatients	Multigene PGx	Prospective implementation	Clinical interpretation support within team	Genomic prescribing concordance	Prospective evaluation
VA specialty service	Hematology/oncology clinic	Therapy-relevant PGx	Clinician/pharmacist-triggered	Leads PGx service and recommendations	Treatment-related recommendation	Specialty integration
Behavioral-health service	Underserved integrated clinic	Psychiatric PGx	Multidisciplinary clinical service	Interpretation and team consultation	Medication recommendation	Local service integration

Clinical integration pathways

Implementation pathways differed primarily in where pharmacogenomic information entered care and who converted it into a medication decision. Lessons from PREPARE indicate that large-scale implementation depends on coordination among testing, interpretation, reporting, professional education, clinical workflow, and health-system infrastructure rather than on genotyping alone [32]. These components can be assembled differently across health systems and therefore should not be interpreted as a mandatory chronological sequence.

A second pathway begins with a well-defined gene–drug decision. The UK CYP2C19–clopidogrel guideline illustrates how a test result can be translated into an explicit therapeutic recommendation when the evidence, phenotype interpretation, and prescribing consequence are sufficiently specified [33]. Such guidance creates an actionable bridge, but it remains therapy-specific and does not establish that every pharmacogenomic result should trigger medication modification.

Routine genotype-guided pharmacotherapy adds another layer because information must persist beyond the initial testing encounter. Single-site implementation experience emphasizes workflow design, clinician engagement, interpretive support, and infrastructure as conditions for embedding pharmacogenomics into ordinary care [34]. On this basis, the review proposes a pathway typology organized by entry point and translation mechanism rather than by presumed effectiveness.

This typology also separates pathway completion from pathway quality. Reaching a prescribing decision does not establish that the decision was clinically superior, patient-preferred, timely, equitable, or sustainable. Conversely, absence of an immediate medication change may be appropriate when the current regimen is already concordant or when a result is intended for future prescribing. **Table 2** makes these routes and their characteristic failure points explicit.

Table 2. Distinct routes by which a pharmacogenomic result can reach—or fail to reach—a prescribing decision

Integration pathway	Entry point	Result delivery	Interpretation actor	Decision-support mode	Pharmacist contribution	Prescribing action / typical failure point
Guideline-linked gene–drug route	Specific treatment decision	Report or EHR result	Prescriber/pharmacist	Guideline-linked recommendation	Interpret and contextualize	Drug/dose change; failure if guidance is unavailable or ignored
Pre-emptive EHR route	Result generated before prescribing	Structured longitudinal record	Automated logic plus clinician	Point-of-prescribing CDS	Build, review, or respond to CDS	Action when future exposure occurs; failure if result is inaccessible
Pharmacist-mediated route	Medication review or testing encounter	Pharmacist report/consultation	Pharmacist	Human interpretation with optional CDS	Initiate, interpret, recommend	Prescriber accepts/modifies therapy; failure at communication or authority boundary
Therapy-specific dosing route	Defined drug initiation	Protocol-linked result	Specialist team	Protocol/order-set support	Coordinated dose interpretation	Genotype-guided initial dose; failure if testing arrives too late
Multidisciplinary service route	Specialty or integrated clinic	Shared team workflow	Care team	Mixed electronic and consultative support	Interpret and coordinate	Team medication decision; failure if ownership is unclear

Decision-support modalities and workflow embedding

Decision support varied in both technical form and clinical timing. The earlier scoping evidence showed substantial heterogeneity in how pharmacogenomic information was surfaced to clinicians, meaning that “CDS

implemented” is too coarse a descriptor for cross-study interpretation [5]. Structured genomic data within an EHR can support persistent result availability and point-of-prescribing guidance, but platform integration is an enabling condition rather than evidence that the resulting recommendation will be followed [7].

Context also changes the meaning of an alert. Refining tricyclic-antidepressant pharmacogenomic CDS with dosing criteria changed which situations triggered decision support, illustrating that clinical relevance depends partly on medication context rather than genotype alone [24]. This is important for alert-burden interpretation: fewer alerts may reflect improved targeting, but an alert count cannot itself establish better prescribing or patient outcomes.

Workflow embedding was also therapy dependent. Pre-emptive programs require results to remain available until a future prescribing event [21], whereas CYP3A5-guided tacrolimus dosing requires testing and interpretation to align with transplant timing, initial-dose selection, and subsequent therapeutic monitoring [25]. Routine implementation therefore involves at least three separable CDS questions: whether the result is technically retrievable, whether support appears at a meaningful decision point, and whether its recommendation is sufficiently contextualized for action. The ACCOuNT findings further caution that even encountered decision support need not produce a measurable improvement in prescribing concordance [26].

Pharmacist roles across testing and prescribing

Pharmacist participation crossed several stages of the testing-to-action pathway. In health-system implementations, pharmacy services can contribute to program design, test selection, laboratory relationships, reimbursement planning, result interpretation, education, and medication recommendations [20]. In specialty practice, a clinical pharmacist practitioner can operate as the principal pharmacogenomic service lead within the care team rather than merely as an external consultant [22].

Primary-care evidence extends this role further upstream. Pharmacist-initiated pre-emptive testing demonstrates that pharmacists may identify candidates and initiate the testing process before a prescriber encounters an actionable result [29]. Community-pharmacy evidence, however, shows that this role cannot simply be transferred across settings. Community pharmacists may face different access to clinical records, reimbursement arrangements, prescriber communication channels, and organizational resources [6]. Contemporary community-pharmacy implementation work likewise identifies professional and organizational conditions that shape whether testing and recommendations can be sustained in routine practice [8].

The review therefore does not define a single “pharmacist role.” Instead, pharmacist contribution is best charted by function: test initiation, patient education, interpretation, clinical contextualization, recommendation generation, communication, follow-up, or implementation governance. Community evidence remains heterogeneous across these functions [30]. Multidisciplinary behavioral-health implementation adds another configuration in which pharmacists contribute within a shared clinical service rather than through a stand-alone pharmacy pathway [31].

Implementation barriers, enablers, and setting differences

Implementation barriers were recurrent but not interchangeable across settings. At health-system level, evidence describes persistent challenges involving reimbursement, informatics, clinical workflow, education, laboratory processes, and professional adoption [2]. Pharmacy-driven implementation experience similarly shows that testing infrastructure and service design must be coordinated with sustainable operational processes rather than treated as independent components [20].

Primary-care evidence emphasizes different combinations of clinician knowledge, time, access, integration, and organizational support [3]. Community-pharmacy implementation adds constraints related to role definition, access to health information, interprofessional communication, reimbursement, and local capacity [8]. These findings do not establish a universal ranking of barriers; a limiting factor in one setting may already be solved infrastructure in another.

Less centralized settings further complicate transferability. Rural implementation demonstrates feasibility within one large system but does not establish readiness across rural care generally [27]. Pharmacist survey evidence from Türkiye points to education and practical experience as important workforce conditions [28], while underserved behavioral-health implementation illustrates how multidisciplinary organization can function as an enabling mechanism in a specific local context [31]. PREPARE likewise shows that implementation choices

remain sensitive to country and system infrastructure [32]. **Table 3** therefore maps configurations rather than presenting a generic barrier checklist.

Table 3. How implementation constraints change across pharmacogenomic pharmacy-practice configurations

Practice configuration	Infrastructure condition	Workflow barrier	Enabling mechanism	Stakeholder role	Sustainability issue	Evidence gap
Academic/large health system	EHR and laboratory integration often available	Embedding PGx at correct decision point	Structured results and CDS	Informatics, pharmacy, prescribers	Maintenance and alert governance	Long-term action/outcome measurement
Primary care	Variable genomic and informatics support	Limited time and integration routes	Clear referral/testing workflow	Pharmacist, GP, laboratory	Reimbursement and role continuity	Comparative implementation models
Community pharmacy	Limited shared-record access may occur	Communication across organizational boundaries	Local champions and defined services	Pharmacist, patient, prescriber	Payment and service ownership	Durable prescribing-action data
Rural health system	Centralized resources may cover dispersed care	Distance, workflow, access variability	System-wide standardized workflow	Pharmacy and prescribing teams	Scalability beyond one network	External transferability
Specialty/integrated clinic	Focused clinical infrastructure	Coordination with disease-specific care	Embedded pharmacist/multidisciplinary team	Specialist, pharmacist, patient	Dependence on local staffing	Replication in other specialties
Multinational implementation	Unequal national infrastructures	Cross-system variation	Shared evidence with local adaptation	Health systems and clinicians	Local implementation capacity	Portability across policy contexts

Evidence gaps and underrepresented practice contexts

The mapped evidence remains uneven in setting, population, and outcome maturity. Published CDS implementations have historically been concentrated in institutions with substantial informatics capacity [5], while community-pharmacy evidence remains heterogeneous and often focused on feasibility or implementation processes rather than sustained prescribing outcomes [30]. Single-site experience is valuable for understanding operational mechanisms, but it cannot establish external generalizability across organizations with different resources, governance, populations, or prescribing cultures [34].

Population representation also requires attention. ACCOuNT directly examined implementation among African American inpatients and is especially informative because frequent use of pharmacogenomic information did not translate into a statistically significant reduction in discordant prescribing [26]. This finding supports future evaluations that measure enacted medication decisions rather than assuming utility from information exposure. Evidence from Türkiye identifies workforce preparation as another context-sensitive gap [28], while the underserved behavioral-health service demonstrates a setting that is represented but remains comparatively uncommon in the implementation literature [31].

Future research should compare implementation configurations prospectively without assuming that one route will dominate across settings. Priority outcomes include time from actionable result to clinical response, recommendation acceptance and nonacceptance, persistence and portability of results, alert burden, pharmacist workload, access, implementation sustainability, and patient-level outcomes where appropriately designed. Primary-care mapping identifies substantial unresolved implementation questions [3], and PREPARE experience supports continued attention to infrastructure and contextual adaptation across systems [32]. These needs define validation targets for the proposed testing-to-action synthesis rather than evidence that the synthesis is already validated.

Conclusion

This scoping review maps pharmacogenomic implementation as a translation problem between genetic testing and medication action. Across diverse practice settings, testing, actionable interpretation, result delivery, decision support, pharmacist recommendation, and enacted prescribing change emerged as related but non-equivalent states. Pharmacists may participate at several of these points, yet their functions and authority depend on the surrounding clinical and organizational configuration.

The evidence does not support treating test availability, CDS deployment, or pharmacist involvement as a proxy for clinical effectiveness. Implementation pathways remain therapy-specific, setting-dependent, and sensitive to infrastructure, workforce capacity, communication, timing, and continuity of results. Null and context-limited findings are therefore as important to interpretation as successful service descriptions.

The principal contribution of this review is a structured map of where translation toward prescribing action occurs and where it can fail. Prospective comparisons, broader practice representation, longitudinal sustainability assessment, and patient-centered outcome evaluation are needed before particular implementation configurations can be considered transferable or reliably effective.

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References

1. Pirmohamed M. Pharmacogenomics: Current status and future perspectives. *Nat Rev Genet.* 2023;24(6):350-62. doi:10.1038/s41576-022-00572-8
2. Smith DM, Douglas MP, Aquilante CL, Deverka PA, Devine B, Dunnenberger HM, et al. Progress in pharmacogenomics implementation in the United States: Barrier erosion and remaining challenges. *Clin Pharmacol Ther.* 2025;118(4):778-89. doi:10.1002/cpt.3736
3. Mai CW, Sridhar SB, Karattuthodi MS, Ganesan PM, Shareef J, Lee EL, et al. Scoping review of enablers and challenges of implementing pharmacogenomics testing in the primary care settings. *BMJ Open.* 2024;14(11):e087064. doi:10.1136/bmjopen-2024-087064
4. Tremmel R, Schreeck F, Jaeger S, Schricker S, Schaeffeler E, Igel S, et al. Clinical implementation of pharmacogenomics and drug-drug interaction screening in a German academic teaching hospital and outpatient follow-up. *Clin Pharmacol Ther.* 2026;119(1):241-54. doi:10.1002/cpt.70083
5. Smith DM, Wake DT, Dunnenberger HM. Pharmacogenomic clinical decision support: A scoping review. *Clin Pharmacol Ther.* 2023;113(4):803-15. doi:10.1002/cpt.2711
6. Aref HAT, Makowsky MJ, Kung JY, Guirguis LM. Mapping the implementation of pharmacogenomic testing in community pharmacies 2003-2021 using the Theoretical Domains Framework: A scoping review. *J Am Pharm Assoc (2003).* 2023;63(2):459-76.e6. doi:10.1016/j.japh.2022.09.019
7. Hall BT, Eken E, Cavallari LH, Duarte JD, Wiisanen KW, Cicali EJ, et al. Implementing pharmacogenomics clinical decision support: A comprehensive tutorial on how to integrate the Epic Genomics module. *Clin Pharmacol Ther.* 2025;117(6):1670-81. doi:10.1002/cpt.3599
8. Kiani P, Bet PM, Jessurun NT, Hoogland P, Mentink J, Swen JJ, et al. Barriers, facilitators, and implementation strategies for pharmacogenomics in community pharmacies: A cross-sectional survey among local champions in pharmacies and key opinion leaders in pharmacogenomics. *Int J Clin Pharm.* 2026;48(2):544-56. doi:10.1007/s11096-025-02022-x
9. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann Intern Med.* 2018;169(7):467-73. doi:10.7326/M18-0850
10. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBIEvid Synth.* 2020;18(10):2119-26. doi:10.1112/JBIES-20-00167
11. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol.* 2018;18(1):143. doi:10.1186/s12874-018-0611-x
12. Peters MDJ, Godfrey C, McInerney P, Khalil H, Larsen P, Marnie C, et al. Best practice guidance and reporting items for the development of scoping review protocols. *JBIEvid Synth.* 2022;20(4):953-68. doi:10.1112/JBIES-21-00242

13. Caudle KE, Whirl-Carrillo M, Relling MV, Hoffman JM, Donnelly RS, Haidar CE, et al. Advancing clinical pharmacogenomics worldwide through the Clinical Pharmacogenetics Implementation Consortium (CPIC). *Clin Pharmacol Ther.* 2025;118(6):1512-22. doi:10.1002/cpt.70005
14. Beunk L, Nijenhuis M, Soree B, de Boer-Veger NJ, Buunk AM, Guchelaar HJ, et al. Dutch Pharmacogenetics Working Group (DPWG) guideline for the gene-drug interaction between CYP2D6, CYP2C19 and non-SSRI/non-TCA antidepressants. *Eur J Hum Genet.* 2024;32(11):1371-7. doi:10.1038/s41431-024-01648-1
15. Bousman CA, Stevenson JM, Ramsey LB, Sangkuhl K, Hicks JK, Strawn JR, et al. Clinical Pharmacogenetics Implementation Consortium (CPIC) guideline for CYP2D6, CYP2C19, CYP2B6, SLC6A4, and HTR2A genotypes and serotonin reuptake inhibitor antidepressants. *Clin Pharmacol Ther.* 2023;114(1):51-68. doi:10.1002/cpt.2903
16. Swen JJ, van der Wouden CH, Manson LEN, Abdullah-Koolmees H, Blagec K, Blagus T, et al. A 12-gene pharmacogenetic panel to prevent adverse drug reactions: An open-label, multicentre, controlled, cluster-randomised crossover implementation study. *Lancet.* 2023;401(10374):347-56. doi:10.1016/S0140-6736(22)01841-4
17. Rethlefsen ML, Brigham TJ, Price C, Moher D, Bouter LM, Kirkham J, et al. Systematic review search strategies are poorly reported and not reproducible: A cross-sectional metaresearch study. *J Clin Epidemiol.* 2024;166:111229. doi:10.1016/j.jclinepi.2023.111229
18. Frandsen TF, Nielsen MFB, Eriksen MB. Avoiding searching for outcomes called for additional search strategies: A study of Cochrane review searches. *J Clin Epidemiol.* 2022;149:83-8. doi:10.1016/j.jclinepi.2022.05.015
19. Rethlefsen ML, Kirtley S, Waffenschmidt S, Ayala AP, Moher D, Page MJ, et al. PRISMA-S: An extension to the PRISMA statement for reporting literature searches in systematic reviews. *Syst Rev.* 2021;10(1):39. doi:10.1186/s13643-020-01542-z
20. Oliver CB, Naik D, Kirkikis M, Ghaffari M, Oyen LJ, Thomas KC. Implementation of pharmacogenomics: Experience at Ochsner Health. *Am J Health Syst Pharm.* 2025;82(6):341-9. doi:10.1093/ajhp/zxae295
21. Tamraz B, Shin J, Khanna R, Van Ziffle J, Knowles S, Stregowski S, et al. Clinical implementation of preemptive pharmacogenomics testing for personalized medicine at an academic medical center. *J Am Med Inform Assoc.* 2025;32(3):566-71. doi:10.1093/jamia/ocae293
22. Dreischmeier E, Hecht H, Crocker E, Seckel E, Wilcox A, Fletcher C, et al. Integration of a clinical pharmacist practitioner-led pharmacogenomics service in a Veterans Affairs hematology/oncology clinic. *Am J Health Syst Pharm.* 2024;81(19):e634-9. doi:10.1093/ajhp/zxae122
23. Pollock D, Peters MDJ, Khalil H, McInerney P, Alexander L, Tricco AC, et al. Recommendations for the extraction, analysis, and presentation of results in scoping reviews. *JBIM Evid Synth.* 2023;21(3):520-32. doi:10.11124/JBIES-22-00123
24. Massmann A, Petry N, Mills S, Adjekum A, Van Heukelom J. Impact of using dosing criteria to refine pharmacogenomic clinical decision support for tricyclic antidepressants. *Am J Health Syst Pharm.* 2025;82(9):e457-64. doi:10.1093/ajhp/zxae337
25. Pasternak AL, Zimmerman C, Park JM. Establishing a CYP3A5 genotype-guided tacrolimus dosing protocol in adult kidney transplant recipients. *Am J Health Syst Pharm.* 2026;83(3):e134-41. doi:10.1093/ajhp/zxaf215
26. Huang Z, O'Leary KJ, Nutescu EA, Jack M, Chen T, Ruhnke GW, et al. Results of the ACCOuNT trial: A multi-institutional prospective pharmacogenomics implementation trial for African American inpatients. *Clin Pharmacol Ther.* 2026;119(1):109-19. doi:10.1002/cpt.70024
27. Petry NJ, Van Heukelom J, Schultz AJ, Jacobsen K, Baye JF, Mills S, et al. Implementation of CYP2C19 and CYP2D6 genotyping to guide antidepressant use in a large rural health system. *Am J Health Syst Pharm.* 2024;81(16):723-32. doi:10.1093/ajhp/zxae083
28. Balaban U, Kocaaslan T, Demirkan K. Insights into pharmacogenetic testing in Türkiye: Pharmacists' knowledge, attitudes, and perceived barriers to implementation. *Sci Rep.* 2026;16:22081. doi:10.1038/s41598-026-53423-5
29. Bank PCD, Swen JJ, Schaap RD, Klootwijk DB, Baak-Pablo R, Guchelaar HJ. A pilot study of the implementation of pharmacogenomic pharmacist initiated pre-emptive testing in primary care. *Eur J Hum Genet.* 2019;27(10):1532-41. doi:10.1038/s41431-019-0454-x

30. Coumau A, Coumau C, Csajka C. Implementing pharmacogenetic testing in community pharmacy practice: A scoping review. *Front Pharmacol.* 2025;16:1659875. doi:10.3389/fphar.2025.1659875
31. Alghamdi BM, Rogers S, Roberman S, Williamson M, Panahi L. Implementation and integration of a multidisciplinary pharmacogenomics service in an underserved integrated behavioral health clinic. *Front Pharmacol.* 2025;16:1594032. doi:10.3389/fphar.2025.1594032
32. Guchelaar HJ, van der Wouden CH, Manson LEN, Abdullah-Koolmees H, Blagec K, Blagus T, et al. Pharmacogenetic implementation studies—lessons learned from the PREPARE study. *Clin Pharmacol Ther.* 2025;118(4):803-12. doi:10.1002/cpt.3749
33. Dello Russo C, Frater I, Kuruvilla R, Lip S, O'Neill H, Burke K, et al. CYP2C19 genotype testing for clopidogrel: A guideline developed by the UK Centre of Excellence in Regulatory Science and Innovation in Pharmacogenomics (CERSI-PGx). *Br J Clin Pharmacol.* 2026;92(2):329-47. doi:10.1002/bcp.70370
34. Cavallari LH, Cicali EJ, Norris M, Nguyen KA, Duarte JD. Genotype-guided pharmacotherapy: The challenges of integrating pharmacogenomic testing into routine healthcare with a focus on experiences at a single site. *Expert Rev Clin Pharmacol.* 2025;18(9):655-67. doi:10.1080/17512433.2025.2568089