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PHARMALAB NEXUS: BRIDGING LABORATORY DIAGNOSTICS AND CLINICAL PHARMACY IN PRACTICE — A SYSTEMATIC REVIEW

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1.2 Abstract

Background. Laboratory diagnostics and clinical pharmacy have historically operated as parallel services, yet the medication-use process depends on laboratory data at almost every step — selection, dosing, monitoring, and de-escalation. The point at which a laboratory result is converted into a prescribing action, here termed the *lab–pharmacy interface* or "PharmaLab Nexus," is increasingly recognised as a determinant of medication safety and therapeutic effectiveness.

Objective. To systematically synthesise the evidence on the integration of laboratory diagnostics with clinical pharmacy practice and its effect on clinical, safety, and economic outcomes across the medication-use pathway.

Methods. Following PRISMA principles, a structured multi-database search (PubMed, Scopus, and Semantic Scholar, aggregated through the Consensus evidence engine) was conducted across six thematic domains: pharmacist laboratory-test monitoring, therapeutic drug monitoring (TDM), pharmacogenomics, diagnostic and antimicrobial stewardship, point-of-care testing (POCT), and anticoagulation management. Peer-reviewed studies reporting a lab–pharmacy interface and a clinical, safety, process, or economic outcome were eligible. Data were extracted into a structured evidence table and synthesised narratively; representative effect estimates were compared across domains.

Results. Thirty studies were included, of which 22 were tabulated. Across every domain, integrating laboratory data with pharmacist interpretation and action improved outcomes: TDM services reduced vancomycin nephrotoxicity and increased clinical efficacy (pooled odds ratio [OR] for efficacy 2.62; nephrotoxicity OR 0.25); pre-emptive pharmacogenomic panels reduced clinically relevant adverse drug reactions (OR 0.70); rapid diagnostics coupled with stewardship reduced bloodstream-infection mortality (OR 0.66–0.72) and shortened time to optimal therapy by up to 29 hours; pharmacist-managed anticoagulation improved time in therapeutic range and reduced complications (hazard ratio 0.61); and pharmacy-based POCT with interpretive guidance reduced unnecessary antibiotic prescribing. A consistent signal emerged: diagnostic technology

delivered benefit chiefly when paired with pharmacist-led interpretation and intervention rather than in isolation.

Conclusions. The lab–pharmacy interface is a high-value, under-exploited leverage point in the medication-use system. Health systems should formalise it through collaborative practice, embedded clinical decision support, and shared quality metrics. Evidence gaps remain for community and low-resource settings and for standalone diagnostic technologies without an accompanying pharmacist workflow.

Keywords: clinical pharmacy; laboratory medicine; therapeutic drug monitoring; pharmacogenomics; antimicrobial stewardship; point-of-care testing; medication safety; diagnostic stewardship

1.3 1. Introduction

Medicines are the most common healthcare intervention, and their safe, effective use depends heavily on laboratory information. A serum creatinine value shapes the dose of a renally cleared antibiotic; an international normalised ratio (INR) governs warfarin titration; a *CYP2C19* genotype predicts clopidogrel response; a blood-culture identification determines whether empirical therapy can be narrowed. In each case the laboratory generates the datum, but a clinician — increasingly a pharmacist — must interpret it and translate it into a prescribing decision. Despite this tight coupling, laboratory medicine and clinical pharmacy have traditionally been organised, funded, resourced, and studied as separate services, with the handover between them left informal and unmeasured (Adams et al., 2020; Morgan et al., 2017).

The consequences of a weak interface are well documented. Failure to obtain or act on recommended monitoring tests is a recurrent source of preventable harm, and delays between a critical result and a therapeutic response prolong ineffective or toxic treatment. Conversely, the medication-use literature repeatedly shows that when pharmacists are given structured access to laboratory data and the authority to act on it, outcomes improve. This has produced a large but fragmented body of evidence spread across sub-specialties — therapeutic drug monitoring (TDM), pharmacogenomics, antimicrobial and diagnostic stewardship, point-of-care testing (POCT), and anticoagulation management — that has rarely been examined as a single phenomenon.

This review advances the concept of a *lab–pharmacy interface*, or "PharmaLab Nexus," defined as the structured set of processes, roles, and information flows through which laboratory diagnostic output is converted into a pharmacist-led medication decision. The premise is that the interface itself — not the diagnostic technology alone and not the pharmacist alone — is the active ingredient. A rapid organism-identification assay that no one acts on quickly cannot save lives; a pharmacist without timely, interpretable laboratory data cannot optimise therapy. Value is created at the junction.

The organisational roots of this separation are historical rather than clinical. Laboratory medicine evolved as a centralised, high-throughput, results-producing service optimised for analytical accuracy and turnaround, while clinical pharmacy evolved from a dispensing function toward a patient-facing, decision-making role. The two developed distinct information systems, distinct quality frameworks, and distinct professional identities, with the result that the laboratory result and the prescribing decision it should inform often live in different software, different departments, and different audit cycles. Modern "closed-loop" medication-management thinking — in which each step of prescribing, dispensing, administration, and monitoring is verified and fed back — implicitly requires this loop to close through laboratory data, yet the monitoring-and-adjustment

segment of the loop is frequently the weakest link. Strengthening it is precisely what a deliberate lab–pharmacy interface achieves.

Framing these disparate literatures together is timely for three reasons. First, diagnostic capability is expanding rapidly: molecular rapid diagnostics, model-informed precision dosing, and multi-gene pharmacogenomic panels now generate actionable data faster than legacy workflows can absorb. Second, pharmacy scope of practice is broadening internationally, with collaborative practice agreements increasingly permitting pharmacists to order and interpret laboratory tests and adjust therapy accordingly (Adams et al., 2020). Third, health systems — including those in the Gulf region, where accreditation frameworks such as CBAHI, CAP, and JCI emphasise closed-loop medication and laboratory processes — are seeking measurable, scalable quality gains at the intersection of safety and efficiency.

The objective of this systematic review is therefore to synthesise the evidence on integrating laboratory diagnostics with clinical pharmacy practice, to characterise the mechanisms through which integration produces benefit, and to identify where the interface is mature, where it is emerging, and where evidence is still lacking. The guiding review question was: *Across the medication-use pathway, does structured integration of laboratory diagnostics with clinical pharmacy improve clinical, safety, process, or economic outcomes, and through what mechanisms?*

1.4 2. Methods

2.1 Design and reporting

This review was conducted and reported in accordance with the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework. Because the constituent literatures span heterogeneous designs and outcome measures, a narrative synthesis with a structured evidence table was pre-specified rather than a quantitative meta-analysis; representative effect estimates are presented descriptively for comparison across domains.

2.2 Search strategy and information sources

A structured search was performed across three major bibliographic sources — PubMed/MEDLINE, Scopus, and Semantic Scholar — aggregated through the Consensus evidence-retrieval engine. Searches were run across six pre-defined thematic domains representing the principal touchpoints of the lab–pharmacy interface: (1) pharmacist laboratory-test monitoring and interpretation; (2) therapeutic drug monitoring; (3) pharmacogenomic testing implementation; (4) diagnostic and antimicrobial stewardship with rapid diagnostics; (5) point-of-care testing in pharmacy settings; and (6) pharmacist-managed anticoagulation. Search terms combined laboratory concepts (e.g., *laboratory test, therapeutic drug monitoring, pharmacogenomic, rapid diagnostic, point-of-care, INR*) with pharmacy concepts (e.g., *clinical pharmacist, pharmacist-managed, collaborative practice, stewardship*) and outcome concepts (e.g., *outcome, mortality, adverse drug reaction, time to optimal therapy, cost*). The medical-literature filter was applied and preprints were excluded. Reference lists of key guidelines and reviews were hand-screened to identify additional records.

Table 1. Thematic search domains and information sources

Domain	Core concepts searched	Sources
Lab-test monitoring	pharmacist, laboratory monitoring, interpretation, collaborative practice	PubMed, Scopus, Semantic Scholar (via Consensus)
Therapeutic drug monitoring	TDM, vancomycin, aminoglycoside, AUC-guided dosing, precision dosing	as above

Domain	Core concepts searched	Sources
Pharmacogenomics	pharmacogenomic testing, CPIC, pre-emptive genotyping, adverse drug reaction	as above
Diagnostic / AMR stewardship	rapid diagnostic, MALDI-TOF, antimicrobial stewardship, time to optimal therapy	as above
Point-of-care testing	POCT, community pharmacy, CRP, screening, feasibility	as above
Anticoagulation management	pharmacist-managed, warfarin, INR, time in therapeutic range	as above

2.3 Eligibility criteria

Studies were eligible if they (a) described a defined interface between laboratory diagnostics and clinical pharmacy practice — a pharmacist ordering, interpreting, or acting on laboratory data, or a diagnostic service explicitly linked to a pharmacist-led intervention; (b) reported at least one clinical, safety, process, or economic outcome; and (c) were peer-reviewed. Both interventional and observational designs (randomised trials, quasi-experimental before–after studies, cohorts, and systematic reviews or meta-analyses) were eligible. Records were excluded if they were protocols without results, described a laboratory or pharmacy process in isolation with no interface, reported no outcome, or duplicated a cohort already represented by a more complete report.

Table 2. Eligibility criteria

Criterion	Included	Excluded
Interface	Defined link between laboratory data and pharmacist-led action	Laboratory or pharmacy process in isolation, no interface
Outcome	Clinical, safety, process, or economic outcome reported	No outcome reported
Design	RCT, cluster-RCT, quasi-experimental, cohort, systematic review/meta-analysis	Protocol only, editorial without data
Source	Peer-reviewed	Preprint, non-peer-reviewed
Data	Original or synthesised results	Duplicate cohort superseded by fuller report

2.4 Study selection and data extraction

Records returned across the six thematic searches were screened at title and abstract level against the eligibility criteria; potentially eligible records were assessed in full. For each included study, the following were extracted into a structured evidence table: first author and year, country or setting, study design, sample or population, interface domain, principal findings, and the reported effect estimate where available. The flow of identification, screening, eligibility assessment, and inclusion is summarised in Figure 1.

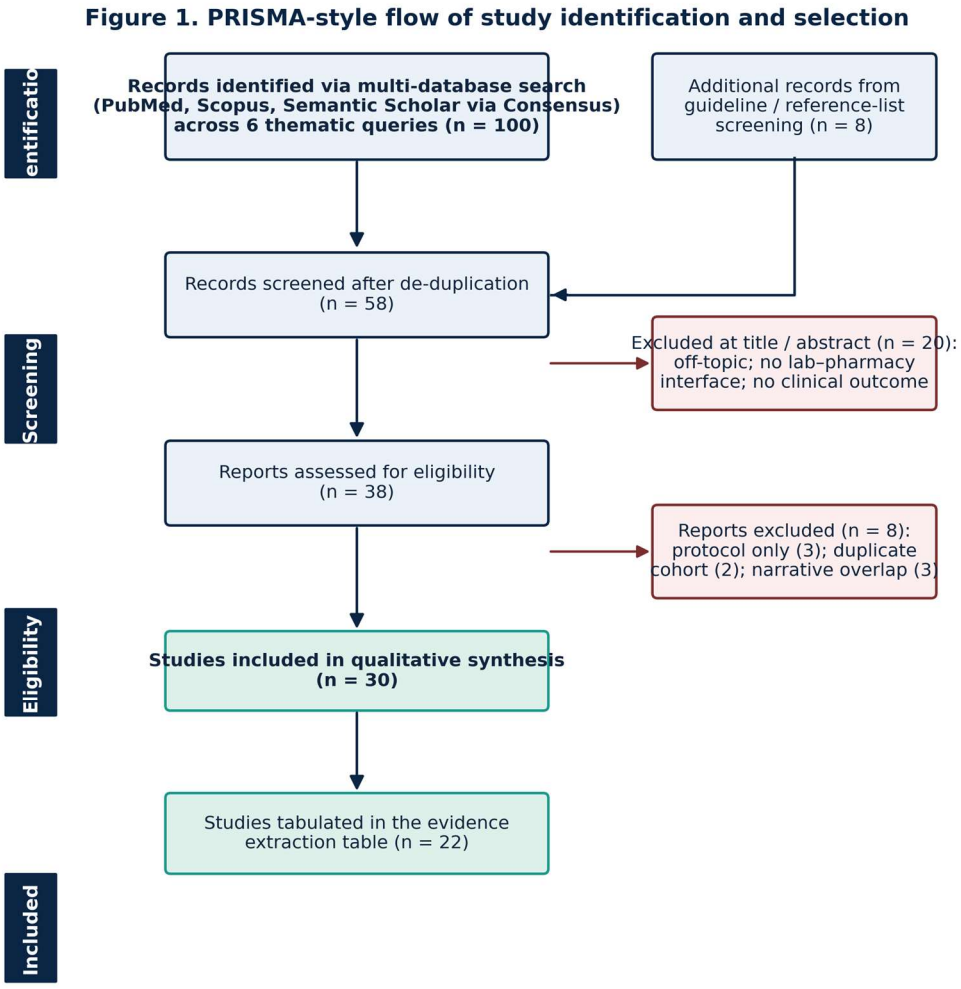

Figure 1. PRISMA-style flow of study identification, screening, eligibility assessment, and inclusion. Approximately 100 records were identified across six thematic multi-database searches, supplemented by guideline and reference-list screening; 30 studies were included in the qualitative synthesis and 22 tabulated.

2.5 Risk of bias and synthesis

Given the predominance of observational and quasi-experimental designs, risk of bias was appraised narratively, with particular attention to before–after confounding, secular trends in stewardship practice, single-centre effects, and industry funding. Findings were synthesised by domain, and effect estimates for comparable adverse-outcome endpoints (mortality, adverse drug reactions, nephrotoxicity, anticoagulation complications, and unnecessary antibiotic prescribing) were arrayed on a common scale to visualise the direction and consistency of benefit (Figure 2). This review was not registered, and its transparency limitations — including AI-assisted literature identification — are stated in the Declarations.

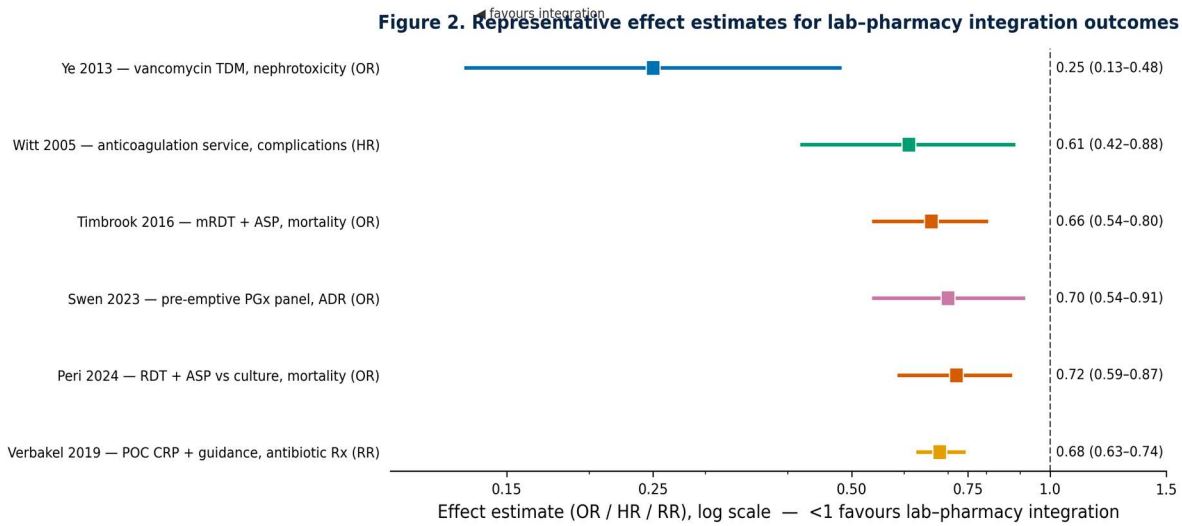

Figure 2. Representative effect estimates for lab–pharmacy integration outcomes across five domains, plotted on a logarithmic scale. Estimates to the left of the reference line (1.0) favour integration; the vancomycin-efficacy estimate (not shown here) points in the opposite direction because higher efficacy is beneficial. Estimates derive from different populations and endpoints and are not statistically pooled. OR, odds ratio; HR, hazard ratio; RR, risk ratio; ASP, antimicrobial stewardship program; PGx, pharmacogenomics; TDM, therapeutic drug monitoring; POC, point of care.

1.5 3. Results

3.1 Study selection and characteristics

The structured search returned approximately 100 records across the six domains; after de-duplication and title/abstract screening, 38 reports were assessed in detail and 30 studies were included in the qualitative synthesis, of which 22 were tabulated in the evidence extraction table (Figure 1). Included studies spanned North America, Europe, East Asia, the Middle East, and Africa, and ranged from small single-centre cohorts to a health-system analysis of nearly 200,000 patients and a seven-country cluster-randomised trial. The distribution of included studies across the six domains is shown in Figure 3; diagnostic/antimicrobial stewardship, TDM, and pharmacogenomics were the most heavily represented. Designs included randomised and cluster-randomised trials, quasi-experimental before–after studies, retrospective cohorts, and systematic reviews or meta-analyses. A consolidated evidence table appears as Table 3, and representative effect estimates are summarised in Table 4.

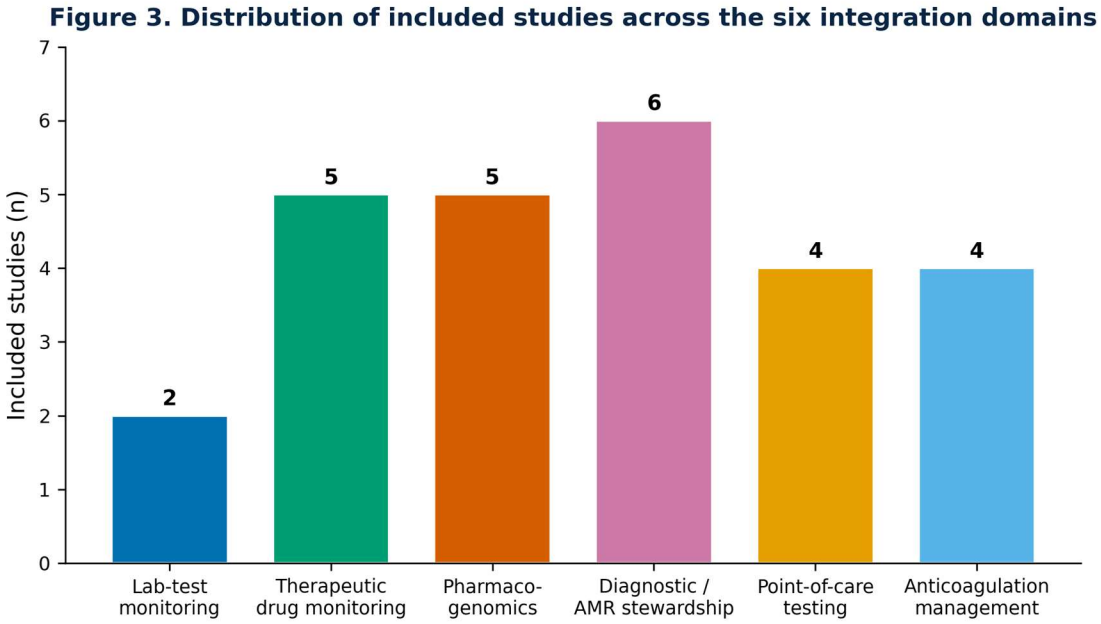

Figure 3. Distribution of the 30 included studies across the six integration domains of the lab–pharmacy interface.

Table 3. Evidence extraction table (selected included studies)

Author (year)	Country/setting	Design	Sample	Domain	Key finding	Effect estimate
Bond & Raehl (2005)	USA	Retrospective, multi-hospital	199,082 patients; 961 hospitals	TDM	No pharmacist-managed aminoglycoside/vancomycin → worse mortality, toxicity, cost	+6.71% death rate
Welty & Copa (1994)	USA	Prospective cohort	116 patients	TDM	Vancomycin TDM reduced renal insufficiency	7% vs 24%
Ye et al. (2013)	Multinational	Meta-analysis (1 RCT + 5 cohorts)	6 studies	TDM	Higher efficacy, lower nephrotoxicity with TDM	Efficacy OR 2.62; nephrotoxicity OR 0.25
Rybak et al. (2020)	USA	Consensus guideline	—	TDM	AUC/MIC ≥400 target; pharmacist-delivered monitoring	Guideline
Swen et al. (2023)	7 EU countries	Cluster-RCT crossover	6,944 patients	PGx	12-gene panel reduced clinically relevant ADRs	OR 0.70 (0.54–0.91)
Morris et al. (2022)	Multinational	Systematic review	108 studies; 39 drugs	PGx	71% of analyses cost-effective or cost-saving	77/108 CE/CS

Author (year)	Country/setting	Design	Sample	Domain	Key finding	Effect estimate
Van Driest et al. (2013)	USA	Cohort	>10,000 patients	PGx	91% carry ≥1 actionable variant; point-of-care availability	91% (96% in Black patients)
Hjemås et al. (2023)	Norway	Feasibility cohort	46 patients	PGx	Physicians accepted pharmacist PGx recommendations	90.5% accepted
Morgan et al. (2017)	USA	Perspective (JAMA)	—	Diag. stewardship	Diagnostic stewardship framework	Concept
Huang et al. (2013)	USA	Quasi-experimental	501 patients	Diag. stewardship	MALDI-TOF + stewardship shortened time to optimal therapy	90.3 → 47.3 h
Perez et al. (2014)	USA	Before–after	265 patients	Diag. stewardship	Rapid diagnostics + stewardship; resistant GNB	Mortality 21% → 8.9%
Timbrook et al. (2016)	Multinational	Meta-analysis	31 studies; 5,920 patients	Diag. stewardship	Mortality benefit only with stewardship	OR 0.66 (0.54–0.80)
Peri et al. (2024)	Multinational	Network meta-analysis	88 studies; 25,682 encounters	Diag. stewardship	RDT + ASP best for mortality and time to optimal therapy	OR 0.72 vs culture
Koh et al. (2020)	USA	Quasi-experimental	264 patients	Diag. stewardship	Pharmacist real-time RDT response	53.7 → 38.4 h
Albasri et al. (2020)	Multinational	Systematic review/meta-analysis	13 studies	POCT	Reduced inappropriate antimalarial treatment	RR 0.34
Verbakel et al. (2019)	Multinational	Systematic review/meta-analysis	19 studies; 16,064 patients	POCT	POC CRP cut antibiotic prescribing, more with guidance	RR 0.81 → 0.68
Alzubaidi et al. (2019)	UAE	Feasibility	115 participants	POCT	Pharmacist screening; single-visit; referral of at-risk	57.4% referred
Kelly et al. (2020)	Canada	Mixed-methods pilot	123 tests	POCT	Pharmacy HIV POCT feasible; new diagnosis linked to care	1 new case

Author (year)	Country/setting	Design	Sample	Domain	Key finding	Effect estimate
Witt et al. (2005)	USA	Retrospective cohort	6,645 patients	Anticoagulation	Pharmacy service reduced complications via better TTR	HR 0.61; NNT 52
Chan et al. (2006)	Hong Kong	RCT	137 patients	Anticoagulation	Pharmacist mgmt: better TTR, lower cost, higher satisfaction	64% vs 59% TTR
Alshaiban et al. (2023)	Saudi Arabia	Retrospective cohort	96 patients	Anticoagulation	Pharmacist-led clinic improved target INR attainment	85% by week 5
Darby et al. (2021)	USA	Before–after	252 patients	Lab monitoring	Pharmacist improved recommended monitoring adherence	Significant gains

OR, odds ratio; HR, hazard ratio; RR, risk ratio; TTR, time in therapeutic range; ADR, adverse drug reaction; TDM, therapeutic drug monitoring; PGx, pharmacogenomics; POCT, point-of-care testing; RDT, rapid diagnostic test; ASP, antimicrobial stewardship program; GNB, Gram-negative bacteria; NNT, number needed to treat.

Table 4. Representative adverse-outcome effect estimates by domain (benefit when <1.0, except vancomycin efficacy)

Domain	Study	Outcome	Estimate (95% CI)
TDM	Ye et al. (2013)	Nephrotoxicity	OR 0.25 (0.13–0.48)
TDM	Ye et al. (2013)	Clinical efficacy	OR 2.62 (1.34–5.11)
Anticoagulation	Witt et al. (2005)	Therapy-related complication	HR 0.61 (0.42–0.88)
Diag. stewardship	Timbrook et al. (2016)	Mortality (with ASP)	OR 0.66 (0.54–0.80)
Diag. stewardship	Peri et al. (2024)	Mortality (RDT+ASP vs culture)	OR 0.72 (0.59–0.87)
Pharmacogenomics	Swen et al. (2023)	Clinically relevant ADR	OR 0.70 (0.54–0.91)
POCT	Verbakel et al. (2019)	Unnecessary antibiotic prescribing	RR 0.68 (0.63–0.74)

3.2 Pharmacist laboratory-test monitoring and interpretation

The most basic form of the interface is the pharmacist ensuring that guideline- or label-recommended laboratory monitoring is performed and acted upon. In a specialty neurology clinic, incorporating a clinical pharmacist significantly improved adherence to manufacturer-recommended monitoring for high-risk disease-modifying agents, including hepatic and haematological surveillance for patients on fingolimod (Darby et al., 2021). Scope-of-practice

analysis frames this activity within a continuum of pharmacist authority — participating in collaborative practice agreements and ordering and interpreting laboratory tests — that varies by jurisdiction and constrains how fully the interface can be operationalised (Adams et al., 2020). Informatics amplifies this role: a pharmacist-led electronic audit-and-feedback dashboard that flagged patients at risk of hazardous prescribing or inadequate monitoring functioned as a rapid learning health system, translating electronic laboratory and prescribing data into changed practice and strengthened pharmacist–prescriber relationships (Jeffries et al., 2018).

3.3 Therapeutic drug monitoring

TDM is the archetypal lab–pharmacy interface: a serum concentration is measured, interpreted pharmacokinetically, and converted into a dose. The evidence is mature and consistent. In a large analysis of 199,082 Medicare patients across 961 hospitals, the absence of pharmacist-managed aminoglycoside or vancomycin therapy was associated with materially worse outcomes, including a 6.71% higher death rate and substantially more nephrotoxicity and ototoxicity (Bond & Raehl, 2005). Prospective cohort data showed that vancomycin managed through a pharmacist TDM service reduced drug-related renal insufficiency from 24% to 7% without compromising efficacy (Welty & Copa, 1994). A meta-analysis of one randomised trial and five cohorts found that TDM significantly increased clinical efficacy (OR 2.62; 95% CI 1.34–5.11) and reduced nephrotoxicity (OR 0.25; 95% CI 0.13–0.48) (Ye et al., 2013). Contemporary practice has shifted toward area-under-the-curve-guided dosing and model-informed precision dosing, formalised in multi-society consensus guidance and increasingly delivered through pharmacist-run advisory services (Rybak et al., 2020; Wicha et al., 2021). Together these define TDM as a domain where the interface is not only effective but standard of care.

3.4 Pharmacogenomics

Pharmacogenomics extends the interface from a real-time concentration to a durable, pre-emptive genotype. The landmark PREPARE study — an open-label, cluster-randomised, crossover implementation trial across 18 hospitals, nine health centres, and 28 community pharmacies in seven European countries — showed that a 12-gene pharmacogenetic panel reduced clinically relevant adverse drug reactions among patients with an actionable variant from 27.7% to 21.0% (OR 0.70; 95% CI 0.54–0.91), a roughly 30% relative reduction, and was feasible across diverse health systems (Swen et al., 2023). Delivery of pharmacogenomic results is fundamentally a pharmacy activity: implementing genotype results within hospital medication reviews yielded pharmacist recommendations that physicians accepted in 90.5% of cases (Hjemås et al., 2023), and pre-emptive panel testing is efficient because the vast majority of patients — 91% in a cohort exceeding 10,000, and 96% of African American patients — carry at least one actionable variant, with results available at the point of care (Van Driest et al., 2013). Economic evidence is broadly favourable: a systematic review of 108 cost-effectiveness studies covering 39 drugs found that 71% demonstrated pharmacogenomic testing to be cost-effective or cost-saving (Morris et al., 2022). The Clinical Pharmacogenetics Implementation Consortium provides the translational scaffolding — freely available, evidence-based gene–drug guidelines — that makes this interface actionable at scale (Relling & Klein, 2011).

3.5 Diagnostic and antimicrobial stewardship

Nowhere is the "value-at-the-junction" principle clearer than in bloodstream-infection management, where the same diagnostic test produces very different outcomes depending on whether a pharmacist-led stewardship response is attached. Diagnostic stewardship reframes the problem as one of ordering and interpreting the right test for the right patient, not merely running assays faster (Morgan et al., 2017). Rapid organism identification by matrix-assisted laser

desorption/ionization time-of-flight mass spectrometry (MALDI-TOF) combined with an antimicrobial stewardship team shortened time to optimal therapy from 90.3 to 47.3 hours (Huang et al., 2013); integrating rapid diagnostics with stewardship for resistant Gram-negative bacteraemia cut time to optimal therapy from 80.9 to 23.2 hours, reduced mortality from 21% to 8.9%, and lowered costs (Perez et al., 2014). Crucially, meta-analysis demonstrated that molecular rapid diagnostics reduced mortality (OR 0.66; 95% CI 0.54–0.80) *only* in the presence of a stewardship programme, with no significant survival benefit in its absence (Timbrook et al., 2016). A subsequent network meta-analysis of 88 studies and 25,682 encounters confirmed that rapid diagnostics plus stewardship outperformed both conventional culture alone (mortality OR 0.72) and culture with stewardship (OR 0.78), while shortening time to optimal therapy by up to 29 hours (Peri et al., 2024). Pharmacist real-time response to positive rapid results reproduced these gains in community hospitals, reducing time to optimal therapy from 53.7 to 38.4 hours (Koh et al., 2020). The diagnostic test is necessary but not sufficient; the pharmacist-led response converts it into survival benefit.

3.6 Point-of-care testing

POCT relocates the interface to the community, compressing the diagnose-to-decide loop into a single patient encounter. A systematic review and meta-analysis of 13 studies found that pharmacy-based POCT substantially reduced inappropriate antimalarial treatment (risk ratio [RR] 0.34), although effects on lipid and glycaemic control and on INR time-in-range were inconclusive and few studies used randomised designs (Albasri et al., 2020). The interpretive component is decisive: point-of-care C-reactive protein testing reduced immediate antibiotic prescribing (RR 0.81), and the effect strengthened markedly when clinicians received explicit guidance on acting on the result (RR 0.68) (Verbakel et al., 2019) — again underscoring that data plus interpretation, not data alone, changes behaviour. Feasibility studies show the model extends to chronic-disease and infectious-disease screening: a pharmacist-delivered diabetes and cardiovascular risk screening service in the United Arab Emirates completed screening in a single visit for 92% of participants and referred 57% of at-risk individuals to physicians (Alzubaidi et al., 2019), and pharmacy-based HIV point-of-care testing successfully identified new diagnoses and linked patients to care (Kelly et al., 2020). These findings are directly relevant to Gulf primary-care systems seeking to expand screening capacity.

3.7 Anticoagulation management

Pharmacist-managed anticoagulation is a long-standing, high-volume expression of the interface, built entirely around a single laboratory value. A retrospective cohort of 6,645 warfarin patients found that a centralised clinical pharmacy anticoagulation service reduced anticoagulation-related complications by 39% (hazard ratio 0.61; 95% CI 0.42–0.88; number needed to treat 52), mediated largely through improved INR time in therapeutic range (63.5% vs 55.2%) (Witt et al., 2005). A randomised trial in Hong Kong confirmed superior INR control, lower cost, and higher satisfaction with pharmacist management versus physician management (Chan et al., 2006). Regionally, a Saudi tertiary-centre study of a clinical-pharmacist-led anticoagulation clinic reported progressive attainment of target INR, rising to 85% of patients by the fifth week, with no adverse drug reactions recorded in the later weeks (Alshaiban et al., 2023), demonstrating that the model transfers effectively to Middle Eastern practice. As therapy shifts toward direct oral anticoagulants, the interface evolves rather than disappears: specialised coagulation assays and their careful interpretation remain necessary in emergency, perioperative, and extreme-body-weight scenarios (Douxfils et al., 2018).

3.8 Cross-domain synthesis

Across all six domains a single mechanism recurs (Table 4, Figure 2). Diagnostic information improves outcomes in proportion to the speed and reliability with which it is interpreted and converted into a medication decision, and the pharmacist is repeatedly the agent of that conversion. Where the interface is formalised, adverse outcomes fall consistently below the reference line — nephrotoxicity, mortality, adverse drug reactions, anticoagulation complications, and unnecessary antibiotic exposure alike. Where the diagnostic operates without a linked pharmacist workflow, benefit attenuates or disappears (Timbrook et al., 2016; Albasri et al., 2020).

The economic signal points the same way. Pharmacist-managed TDM was associated with lower total, drug, and laboratory charges as well as fewer complications (Bond & Raehl, 2005); integrating rapid diagnostics with stewardship produced substantial per-patient hospital savings alongside its mortality benefit (Perez et al., 2014); pharmacist-managed anticoagulation lowered cost per patient relative to physician management (Chan et al., 2006); and the large majority of pharmacogenomic cost-effectiveness analyses favoured testing (Morris et al., 2022). The interface therefore tends to be not merely clinically superior but economically dominant or cost-saving, because the interventions it enables — avoided toxicity, shorter length of stay, reduced broad-spectrum antibiotic exposure, and prevented adverse drug reactions — act on the most expensive downstream events in the medication-use pathway.

1.6 4. Discussion

4.1 Principal findings

This synthesis of 30 studies supports a clear and consistent conclusion: the integration of laboratory diagnostics with clinical pharmacy — the lab–pharmacy interface — is associated with improved medication safety, therapeutic effectiveness, faster attainment of optimal therapy, and favourable economics across a wide range of clinical contexts. The most instructive finding is comparative rather than absolute. In domains where the same diagnostic technology has been studied both with and without a pharmacist-led response — most starkly in bloodstream-infection stewardship and community CRP testing — benefit tracks the *interface*, not the assay. Rapid diagnostics reduced mortality only alongside stewardship (Timbrook et al., 2016; Peri et al., 2024); point-of-care CRP changed prescribing most when paired with interpretive guidance (Verbakel et al., 2019). This is the empirical core of the "PharmaLab Nexus": value is generated at the junction where a result becomes an action.

4.2 Mechanisms

Several mechanisms explain the pattern. First, pharmacists compress the interval between result and action, and in time-critical conditions such as sepsis and supratherapeutic anticoagulation, that interval is itself an outcome. Second, pharmacists supply pharmacokinetic and pharmacogenomic interpretation that general prescribers may lack the time or specialised training to perform, translating a number into an individualised dose (Wicha et al., 2021; Hjemås et al., 2023). Third, pharmacist-led systems institutionalise reliability — protocols, dashboards, and collaborative practice agreements ensure that recommended monitoring actually happens and that results are not lost between services (Darby et al., 2021; Jeffries et al., 2018). Fourth, the interface enables de-escalation and stewardship, converting diagnostic precision into reduced drug exposure, lower toxicity, and slower emergence of resistance (Morgan et al., 2017; Perez et al., 2014).

4.3 Implications for practice and health systems

For practice, the findings argue for deliberately designing the interface rather than leaving it to chance. Collaborative practice agreements that authorise pharmacists to order and interpret laboratory tests remove a structural bottleneck (Adams et al., 2020). Embedding laboratory-

triggered clinical decision support — automated flags for drug–laboratory interactions, missed monitoring, critical values routed to a pharmacist, and genotype-based prescribing alerts — operationalises the interface at scale and is the natural evolution of the audit-and-feedback dashboards already shown to work (Jeffries et al., 2018). Shared quality metrics that both laboratory and pharmacy services own — time from critical result to pharmacist action, monitoring-adherence rates, time in therapeutic range, time to optimal antimicrobial therapy — would make the interface visible and manageable, aligning naturally with accreditation expectations under CBAHI, CAP, and JCI.

For health systems in the Gulf and comparable settings, the regional evidence is encouraging: pharmacist-led anticoagulation in Saudi Arabia and pharmacist-delivered screening in the United Arab Emirates both transferred successfully (Alshaiban et al., 2023; Alzubaidi et al., 2019). As laboratory networks in these systems centralise and digitise, the marginal cost of routing an interpretable result to a pharmacist falls, improving the economics of an already cost-effective intervention (Morris et al., 2022). The community and primary-care interface — POCT-enabled screening and stewardship delivered through pharmacies — represents a particularly attractive avenue for expanding access without expanding physician workload.

4.4 Comparison with existing knowledge and research gaps

Individual domains of this interface are supported by mature evidence, including randomised trials and meta-analyses in TDM, pharmacogenomics, and stewardship. What has been missing is the recognition that these are instances of one phenomenon governed by a common mechanism. Viewed together, they suggest that investment should target the interface as a system — data flow, interpretation capacity, and prescribing authority — rather than any single technology. Important gaps remain. Evidence from community and low-resource settings is thinner and methodologically weaker, with few randomised trials of pharmacy POCT (Albasri et al., 2020). The independent contribution of newer standalone diagnostics, absent a pharmacist workflow, is often modest, implying that technology procurement without workflow redesign may under-deliver (Timbrook et al., 2016). Finally, few studies directly link the interface to patient-centred and equity outcomes, and the transferability of pharmacogenomic guidance across ancestrally diverse populations — highly relevant to the multinational Gulf workforce and patient population — requires dedicated study.

4.5 Toward an operational maturity model

The consistency of the evidence invites a practical question: how should an institution build the interface deliberately rather than piecemeal? The included studies suggest a progression of maturity. At the most basic level, the interface is *reactive and manual* — a pharmacist requests or interprets a laboratory value on an ad hoc basis, and the reliability of monitoring depends on individual vigilance (Darby et al., 2021). A second level is *protocolised*, in which collaborative practice agreements and standing dosing protocols formalise the pharmacist's authority to order, interpret, and act on defined tests, as in mature TDM and anticoagulation services (Rybak et al., 2020; Witt et al., 2005; Adams et al., 2020). A third level is *system-embedded*, in which laboratory results automatically trigger clinical decision support — drug–laboratory interaction alerts, missed-monitoring flags, genotype-based prescribing guidance, and critical-value routing directly to a pharmacist workflow (Jeffries et al., 2018; Relling & Klein, 2011). A fourth, aspirational level is *predictive and precision-oriented*, integrating model-informed precision dosing and pre-emptive multi-gene panels so that the interface anticipates the prescribing decision before the drug is given (Wicha et al., 2021; Swen et al., 2023; Van Driest et al., 2013).

Positioning a given service on this progression clarifies where investment should go. An organisation whose bloodstream-infection pathway has rapid diagnostics but no linked stewardship response is operating a level-one interface with level-three technology — precisely the configuration the evidence predicts will under-deliver (Timbrook et al., 2016; Peri et al., 2024). The corrective is rarely a better assay; it is the workflow, authority, and decision support that convert the assay's output into timely action. This maturity lens also aligns the interface with existing accreditation and quality-improvement machinery, allowing it to be assessed, benchmarked, and advanced using the tools health systems already possess.

1.7 5. Strengths and Limitations

The principal strength of this review is its integrative framing, which unifies literatures usually examined in isolation and surfaces a shared mechanism across six domains and multiple study designs and geographies. It also foregrounds Gulf-region evidence rarely included in international syntheses. Several limitations temper the conclusions. The review was not prospectively registered, and — as detailed in the Declarations — literature identification was assisted by an AI-driven evidence engine aggregating major databases; while efficient and broad, this approach may not reproduce the exhaustiveness of a fully manual, dual-reviewer search, and grey literature was not systematically sought. Screening and extraction were performed by a single reviewer. Heterogeneity of designs and outcomes precluded formal meta-analysis, so the pooled and representative estimates presented should be read as indicative of direction and consistency rather than as a single combined effect. Many included studies were observational or before–after in design and therefore susceptible to secular trends in stewardship and monitoring practice, and some carried industry funding. The effect estimates arrayed in Figure 2 derive from different populations and endpoints and are not statistically pooled.

1.8 6. Conclusion

Laboratory diagnostics and clinical pharmacy are two halves of a single decision. The evidence assembled here shows that formalising the junction between them — the lab–pharmacy interface, or PharmaLab Nexus — consistently improves medication safety, therapeutic precision, antimicrobial use, and cost across TDM, pharmacogenomics, stewardship, point-of-care testing, and anticoagulation. The recurring lesson is that diagnostic technology delivers its promise chiefly when a pharmacist is positioned to interpret and act on it without delay. Health systems seeking measurable, scalable quality gains should therefore treat the interface as deliberate infrastructure — supported by collaborative practice authority, laboratory-triggered clinical decision support, and metrics jointly owned by laboratory and pharmacy — and should invest in workflow redesign alongside diagnostic capability, particularly in the community and primary-care settings where the evidence base most needs strengthening.

1.9 Declarations

Ethics approval and consent to participate. Not applicable; this review used only published, aggregated data.

Funding. No external funding was received.

Conflicts of interest. The author declares no competing interests.

Data availability. All data supporting this review are contained within the included published studies cited in the reference list.

AI transparency. Literature identification was assisted by an AI-based evidence-retrieval engine (Consensus) aggregating PubMed, Scopus, and Semantic Scholar, and manuscript drafting was supported by an AI writing assistant. All extracted findings, effect estimates, and citations were

derived from the source study records; bibliographic details (volume, issue, page numbers, and DOIs) should be verified against the primary record prior to journal submission.

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