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Systematic review

Enhancing diagnostic accuracy and pre-analytical efficiency: a systematic review of workflow coordination among laboratory specialists, medical laboratory technologists, and patient care technicians

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Abstract

Background: Pre-analytical failures during test ordering, patient identification, specimen collection, labeling, handling, and transport threaten diagnostic accuracy and delay clinical decisions. This review evaluated workflow coordination in laboratory specialists, medical laboratory technologists, and patient care technicians and collectors. Methods: PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Library were searched for studies published from 2000 through Jun 2026. Eligible studies evaluated coordinated interventions or factors linked to specimen identification errors, rejection, hemolysis, turnaround time, or collection knowledge. Findings were synthesized narratively because interventions, settings, denominators, and outcome definitions were heterogeneous. Results: Seventeen original studies were included. Bedside barcode identification, electronic ordering, and mobile specimen-labeling systems produced the most consistent reductions in mislabeled specimens and wrong-blood-in-tube events. Multidisciplinary programs combining standardized procedures, competency assessment, consumable redesign, surveillance, and feedback also reduced rejection and hemolysis. Education improved knowledge more than specimen outcomes, with one quasi-experimental study reporting no significant reduction in rejection. Most studies used uncontrolled before-after or retrospective designs, limiting causal certainty. Conclusions: Closed-loop coordination connecting clinical ordering, bedside collection, immediate

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labeling, transport, laboratory acceptance, and feedback strengthens pre-analytical performance. Technology achieved greater benefit when integrated with role clarity, monitoring, and recurrent competency assessment. Future controlled studies need standardized indicators and direct measures of diagnostic delay, treatment change, patient harm, and cost.

Keywords: pre-analytical phase; diagnostic accuracy; laboratory workflow; specimen rejection; patient identification; medical laboratory technologists; patient care technicians; phlebotomy; hemolysis; quality improvement.

Introduction

Clinical laboratory results affect diagnosis, triage, treatment selection, monitoring, and discharge decisions (1). The pre-analytical pathway begins with test selection and ordering, continues through patient preparation, identification, collection, labeling, handling, and transport, and ends when a specimen is ready for analysis (2). Contemporary reviews identify this extended pathway as the most error-prone portion of the total testing process because it crosses locations, professional groups, information systems, and handoff points (3). Failures at these interfaces alter specimen identity or composition before analytical quality controls begin, leaving laboratory instruments unable to detect every clinically important defect (1,3).

Workflow fragmentation is important to this risk because laboratory specialists establish acceptance rules and quality indicators, medical laboratory technologists evaluate specimen integrity and process samples, and patient care technicians or comparable collectors perform bedside tasks under time pressure (4). Inconsistent terminology and denominators in institutions also weaken benchmarking, since errors are reported per request, tube, specimen, patient, or collection episode (4). Harmonized monitoring requires shared definitions, visible ownership, and feedback connecting laboratory findings with the clinical unit where the specimen originated (5). Continuous quality indicators convert isolated rejection events into operational signals that identify recurrent risks by ward, shift, collector group, and error type (2,5). This perspective treats specimen quality as a shared process rather than a laboratory-only responsibility (5).

Patient misidentification and labeling failures represent high-severity events because a technically accurate result becomes attached to the wrong person or specimen (6). Evidence reviews of barcoding and bedside identification report reductions when electronic orders, wristband verification, and immediate label printing operate as one closed loop rather than separate technologies (6,7). Hemolysis, clotting, insufficient volume, contamination, incorrect containers, and delayed transport create a second group of failures that produce rejection, recollection, delayed treatment, and distorted analyte concentrations (8).

Many interventions address phlebotomy education, while the underlying pathway depends on coordinated behavior among clinical collectors, laboratory technologists, supervisors, educators, and information-technology personnel (1,7). A role-focused synthesis is needed to determine which coordination models improve measurable pre-analytical outcomes and which strategies produce knowledge gains without reliable changes in specimen quality. This systematic review examined

workflow coordination among laboratory specialists, medical laboratory technologists, and patient care technicians or equivalent frontline collectors, with specimen error rates as primary outcomes and turnaround time, recollection, and knowledge as secondary outcomes.

Methods

Design and eligibility

This review followed PRISMA 2020 principles and used a population–workflow–outcome framework (Fig 1). Eligible reports were original quantitative or mixed-method studies published from 2000 through 2026 in hospitals, emergency departments, outpatient services, oncology centers, transfusion services, or primary care. Studies had to evaluate a coordinated pre-analytical intervention, an organizational exposure, or a quality-monitoring program involving laboratory personnel and frontline specimen collectors. Nurses, phlebotomists, health technicians, emergency staff, and delegated bedside collectors were treated as patient-care-technician equivalents when their reported duties included patient identification, collection, labeling, or specimen transfer. Reviews, editorials, case reports, analytical-device validation studies, and studies without measurable workflow outcomes were excluded.

Information sources and search strategy

The planned databases were PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Library. Search concepts combined laboratory personnel terms with collector-role terms, pre-analytical workflow terms, and outcomes: ("laboratory specialist" OR "medical laboratory technologist" OR phlebotomist) AND ("patient care technician" OR nurse OR collector) AND (preanalytical OR collection OR labeling OR transport OR hemolysis) AND (error OR rejection OR "turnaround time" OR accuracy). Reference lists of eligible studies and relevant systematic reviews were examined for additional records.

Selection, extraction, and outcomes

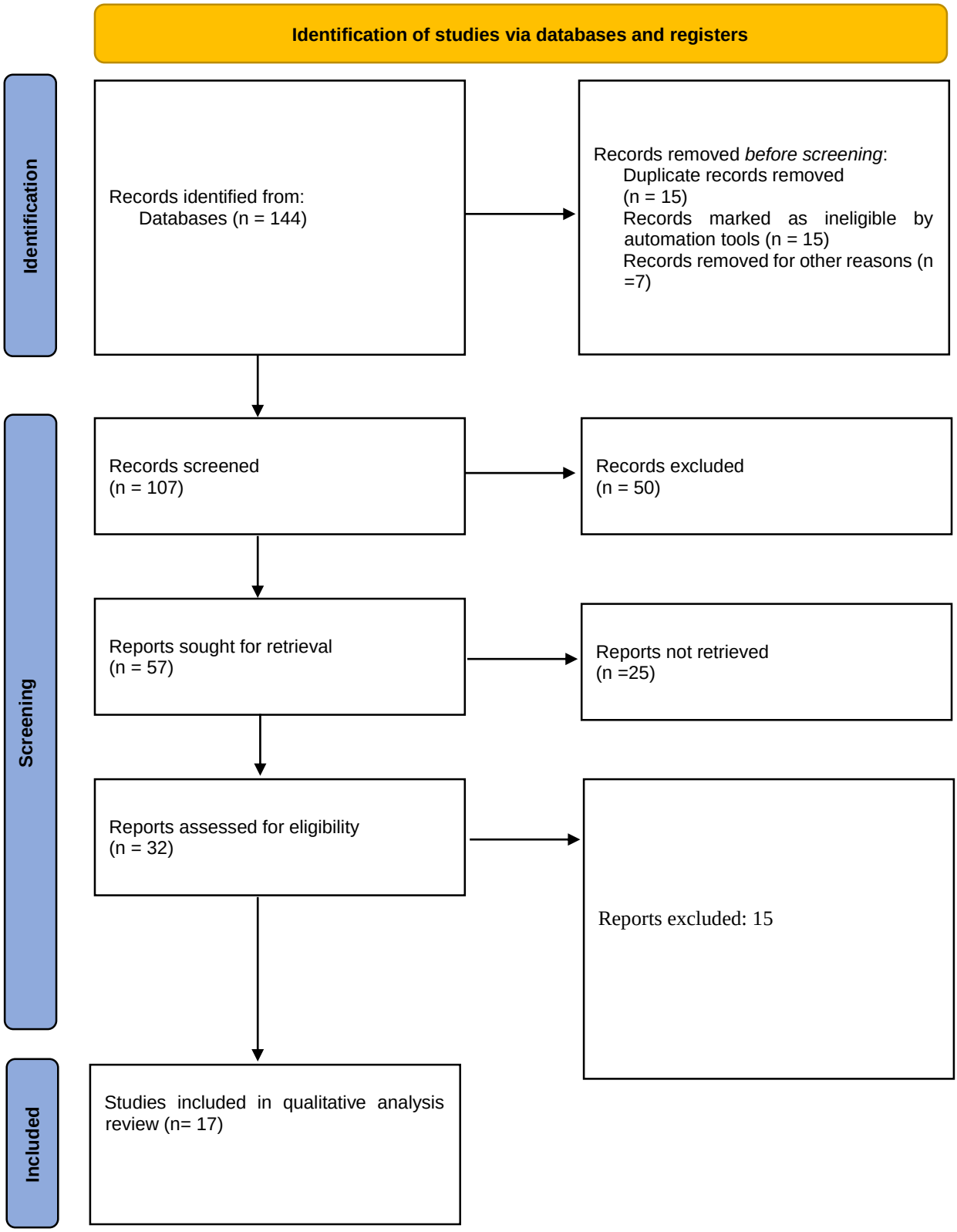
One reviewer screened titles and abstracts, assessed full texts, and repeated eligibility decisions during a second pass. A standardized form captured publication year, country, setting, participating roles, design, sample size, intervention components, comparator, definitions, and numerical outcomes. Primary outcomes were labeling or identification errors, wrong blood in tube, rejection, hemolysis, clotting, insufficient volume, incorrect container, and contamination. Secondary outcomes were collection-to-analysis time, recollection, staff knowledge, and sustained performance.

Quality appraisal and synthesis

Design-specific Joanna Briggs Institute criteria informed appraisal of sampling, exposure measurement, outcome ascertainment, confounding, follow-up, and statistical analysis. Intervention studies were also examined for concurrent changes, secular trends, adherence measurement, and objective outcome capture. Studies were grouped into identification technology, multidisciplinary process redesign, education and competency management, and laboratory surveillance with feedback. Meta-analysis was not performed because interventions, denominators, settings, and outcome definitions

differed; effect directions and estimates were synthesized narratively.

Fig 1: PRISMA consort chart



Results

We include seventeen original studies, comprising multicenter surveys, retrospective cohorts, prospective interventions, and quasi-experimental before-after evaluations in emergency, inpatient, outpatient, oncology, transfusion, and primary-care settings (9-25). Most interventions linked at least two professional or technical nodes, including bedside collectors, laboratory technologists, laboratory quality teams, educators, electronic order systems, and specimen-label printers (10-20).

Identification technology produced the most consistent improvements in specimen identity and labeling outcomes. An emergency-department electronic ordering and barcode workflow reduced labeling errors from 0.42% to 0.11%, while bedside printers reduced annual mislabeled specimens from 103 to 8 in another hospital (11,12). A pediatric oncology system reduced identification errors from 0.03% to 0.005% and was estimated to prevent at least 62 events during its first year, while a positive identification system removed a manual preprinting step associated with frequent opportunities for error (13,14). A 10-year hospital program combining restrictive acceptance rules, barcode identification, and automated labeling achieved relative reductions of 92% to 99% in inpatient, outpatient, and emergency services (15). Mobile collection technology reduced mislabeled specimens from 0.020% to 0.003% and decreased collections exceeding 60 minutes by 27%, while electronic identification reduced wrong-blood-in-tube events from 1 per 10,110 manually labeled samples to 1 per 35,806 electronically labeled samples (16,17).

Multicomponent redesign improved hemolysis and rejection outcomes when education was connected to equipment, procedures, monitoring, and feedback (10,18-20,25). In an emergency department, coordinated changes to collection technique and equipment reduced hemolysis from 19.8% to 4.9% and shortened sampling-to-analysis time from 60.8 to 48.4 minutes (10). A Korean quality program reduced total pre-analytical errors from 0.42% to 0.32% while staff knowledge increase from 46.0 to 71.5, and an oncology center reported rejection falling from 0.19% to 0.05% in its intervention period (18,19). A multidisciplinary hospital initiative reduced rejected specimens from 1.43% to 0.47%, while sensitization of medical, nursing, and laboratory staff reduced quantity-not-sufficient rejection from 5.64% to 4.05% (20,25).

Across 147 laboratories, Wagar et al. observed 0.92 labeling errors per 1,000 labels in more than 3.3 million labels (9). These associations reinforced the value of laboratory governance and service availability with collector-level interventions (9). Education produced less uniform specimen outcomes than integrated redesign (23-25). Training in one hospital increased phlebotomy knowledge from 58.9% to 91.8% and reduced rejection from 2.35% to 1.56%, whereas a four-facility primary-care study improved knowledge without a statistically significant reduction in rejection (23,24). Surveillance studies showed persistent concentration of failures in inpatient workflows, nonworking hours, and a limited set of causes, including insufficient volume, clotting, and missing specimens (21,22). Risk of bias was moderate to serious because most intervention studies lacked concurrent controls and remained vulnerable to secular trends, simultaneous policy changes, and altered reporting, although laboratory information systems supplied objective outcome counts in many studies (9-25). Characteristics of the

included studies and main findings presented in Table 1 & 2.

Table 1. Characteristics and principal outcomes of coordinated workflow studies

Study	Design and setting	Coordination strategy	Principal result
Wagar et al., 2008 (9)	Multicenter Q-Probes; 147 laboratories	Identification monitoring and inpatient phlebotomy availability	0.92 errors per 1,000 labels; lower rates with quality monitors and 24-hour phlebotomy.
Ong et al., 2009 (10)	Prospective phased ED intervention	Collector education, technique change, and equipment redesign	Hemolysis fell from 19.8% to 4.9%; sampling-to-analysis time fell by 12.4 minutes.
Hill et al., 2010 (11)	ED before-after study	Electronic ordering, barcode verification, and system-generated labels	Labeling errors fell from 0.42% to 0.11%.
Brown et al., 2011 (12)	Hospital quality-improvement study	Barcode technology and bedside printers	Annual mislabeled specimens fell from 103 to 8.
Hayden et al., 2008 (13)	Pediatric oncology before-after study	Electronic positive patient and specimen identification	Errors fell from 0.03% to 0.005%; at least 62 events were estimated as prevented.
Morrison et al., 2010 (14)	Inpatient phlebotomy before-after study	Wristband scanning and barcode identification	Errors fell from 5.45 to 3.2 per 10,000; 108 events were estimated as prevented annually.
Ning et al., 2016 (15)	Ten-year hospital retrospective study	Acceptance policy, barcode identification, and automated labeling	Relative reductions ranged from 92% to 99% across service areas.
Saathoff et al., 2018 (16)	Nonrandomized hospital pre-post study	CPOE, bedside scanning, printing, and electronic documentation	Mislabeling fell from 0.020% to 0.003%; delayed collections fell by 27%.
Kaufman et al., 2019 (17)	Multicenter transfusion retrospective study	Electronic identification at pretransfusion collection	WBIT fell from 1:10,110 manually labeled samples to 1:35,806 electronic samples.
Lee, 2019 (18)	University-hospital quality-improvement study	Error analysis, targeted training, and maintenance	Errors fell from 0.42% to 0.32%; knowledge rose from 46.0 to 71.5.
Chavan et al., 2019 (19)	Prospective oncology-center intervention	Root-cause analysis and redesigned staff training	Rejection fell from 0.36% initially to 0.05% in later years.
Gupta et al., 2021 (20)	Multidisciplinary hospital initiative	Education, observed competency, consumables, orders, and rapid cycles	Rejection fell from 1.43% to 0.47%.

Table 2. Additional included studies and methodological interpretation

Study	Main finding	Appraisal
Alshaghdali et al., 2022 (21)	Among 95,002 hematology samples, errors fell from 11.6% to 6.5%; clotting and missing specimens predominated.	Large objective dataset; retrospective, single-center design.
Dundar and Bahadir, 2023 (22)	Among 7,762,981 requests, rejection was 1.28%; inpatient and nonworking-hour rates were highest.	Strong denominator; exposure and confounding control were limited.
Aykal et al., 2016 (23)	Knowledge rose from 58.9% to 91.8%; rejection fell from 2.35% to 1.56%.	Small collector cohort; uncontrolled pre-post comparison.

Study	Main finding	Appraisal
Abbas et al., 2017 (24)	Knowledge improved, with no statistically significant rejection reduction across four primary-care facilities.	Quasi-experimental multicenter design; heterogeneous facility context.
Agarwal et al., 2012 (25)	Quantity-not-sufficient rejection fell from 5.64% to 4.05% after staff sensitization.	Multiple indicators improved; secular and concurrent changes remained possible.
Overall evidence (9-25)	Technology and multicomponent redesign showed consistent benefit; education alone produced mixed specimen outcomes.	Predominantly moderate-to-serious risk of bias; no quantitative pooling.

Discussion

The findings indicates that pre-analytical performance improves most when coordination is designed as a closed loop (6,7,11-20). Electronic ordering, wristband verification, bedside label generation, laboratory acceptance rules, and traceable feedback reduced opportunities for transcription, delayed labeling, and specimen–patient mismatch at several handoffs (11-17). The magnitude and consistency of these reductions exceeded the changes observed after education alone (12,16,17,23,24).

The findings place laboratory specialists and technologists in an active governance role extending beyond analytical testing (2,5,9,18-22). Their functions included defining rejection criteria, identifying patterns by unit or shift, training collectors, supplying performance feedback, and coordinating corrective action with nursing or clinical leadership (9,18-22). A prospective multicenter study found more collection errors in EDs than in outpatient clinics managed by laboratory professionals (26). European data describe variation in national phlebotomy guidance, education, and competency structures (27).

Training was effective when embedded in recurrent observation, practical competency assessment, standardized supplies, and unit-level feedback rather than delivered as a single educational event (18-20,23-25). The contrasting primary-care study, where knowledge improved without significant rejection reduction, shows that knowledge is an intermediate outcome and does not guarantee reliable execution under workload, staffing, transport, and equipment constraints (24). Hemolysis management requires agreement between clinical units and laboratories regarding detection, rejection, recollection, interpretive comments, and communication of urgent results, rather than reliance on collector instruction alone (8,10,28). These findings support a coordinated operational model comprising verified ordering, two-identifier bedside confirmation, correct container selection, immediate labeling, controlled transport, laboratory integrity assessment, and feedback to the originating unit (5-8,11-22). Specimen integrity is the mechanism linking workflow efficiency to diagnostic accuracy, because hemolysis, clotting, contamination, delayed separation, and misidentification alter or misattribute results (1,3,8,28). Recollection extends decision intervals and exposes patients to repeated venipuncture, while acceptance of compromised specimens risks false interpretation (1,8,10). Thus, reduced rejection alone is not automatically beneficial unless acceptance criteria remain stringent and the decline reflects better collection rather than relaxed laboratory thresholds (2,5,21). Balanced dashboards need error, recollection,

turnaround, and patient-impact measures together (4,5).

Interpretation need caution because most studies were retrospective or uncontrolled before-after evaluations, and several introduced multiple changes simultaneously (10-20,23,25). Objective laboratory information-system counts strengthened outcome ascertainment, although changes in surveillance intensity, rejection policy, staffing, and denominator selection introduced residual confounding (4,9,15,21,22). Few reports used the exact title “patient care technician,” so nurses, phlebotomists, emergency personnel, and health technicians were mapped according to collection duties rather than occupational title (18,22-24). Most outcomes were process surrogates, with limited direct measurement of diagnostic delay, treatment modification, adverse events, or cost (6-8). The single-reviewer draft process and pending subscription-database export counts also limit reproducibility until the bracketed PRISMA fields are completed (4,5). Future cluster-randomized or stepped-wedge studies need role-specific reporting, standardized denominators, implementation fidelity measures, and patient-centered outcomes across varied resource settings (4-8,24).

Conclusion

Coordinated pre-analytical workflows improve specimen identification, reduce rejection and hemolysis, and shorten selected collection intervals when bedside staff, laboratory technologists, quality leaders, and information systems function as one traceable pathway. Barcode identification and immediate bedside labeling produced the strongest and most consistent effects, while education achieved greater operational benefit when combined with competency assessment, standardized equipment, surveillance, and feedback. Health systems need closed-loop processes linking verified orders, patient identification, collection, transport, laboratory acceptance, and unit-level learning, alongside standardized indicators that connect specimen quality with diagnostic delay, treatment decisions, patient harm, recollection burden, and cost across diverse clinical settings.

List of abbreviations

CPOE: computerized provider order entry; ED: emergency department; EFLM: European Federation of Clinical Chemistry and Laboratory Medicine; JBI: Joanna Briggs Institute; LIS: laboratory information system; MLT: medical laboratory technologist; PCT: patient care technician; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; QI: quality indicator; TAT: turnaround time; WBIT: wrong blood in tube.

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